Practical Spectral Imaging Using a Color-Filter Array Digital Camera

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Executive Summary

Imaging is an important technique in the scientific examination of art. Its main use has been for visual documentation. Photographs have long been used to document condition before and after transit, microscopic examinations, conservation treatments, and so on. They are used to enable color reproductions in books and from the Internet. Images using materials with spectral sensitivities in such non-visible regions of the electromagnetic spectrum as infrared and X ray are equally important to the visible spectrum. Although images are used to record scientific examinations, they are used infrequently as an analytical tool, that is, the amount of colorant in a photographic material would be used to relate to physical properties of the art. In contrast, astronomy, remote sensing, and medicine have exploited this capability for many years. The advent of digital imaging offers increased opportunities to exploit images for the scientific examination of art. A research program is underway at Rochester Institute of Technology to develop an image-acquisition system that records reflection information as a function of wavelength. The system initially is limited to the visible region. The program is known as the Art Spectral Imaging Project and the program is documented at http://art-si.org/.

The most important research goal has been to develop a practical imaging system that provides high colorimetric accuracy with reasonable spectral accuracy. In order to be practical, the system should use commercial products to the greatest extent possible. Any hardware modifications should be straightforward. Software should be generalized and based on sound mathematical principles such that it can be written for commercial applications.

This has been accomplished by performing hardware modifications to an area-color-filter-array digital camera, writing extensive software to perform the necessary calibration, image registration, spectral and colorimetric processing, and output to conventional file formats. This technical report describes the imaging system, the color and imaging science (in the form of a submitted manuscript to Studies in Conservation), and a listing of required hardware and software to build an identical system to the Art Spectral Imaging Project camera.

Spectral Imaging System Specification

The system uses commercial software and hardware to the greatest extent possible. The camera system revolves around Sinar AG equipment. The computer is an Apple platform. The printer is an Epson medium or large-format inkjet printer. The camera system is shown in Figure 1. A cost summary is given in Table I. The specific components are listed in Tables II –XI. These were the current costs during April 2005.

Figure 1. Modified Sinar camera system.

Table I. Spectral imaging system costs.

Component	Cost
Camera / Shutter / Lens	$28,313
Digital Back	$31,406
Camera Support	$8,662
Lighting	$13,319
Computer	$17,122
File Server	$17,247
Software	$8,894
Color Calibration	$1,198
Filter Slider	$19,500
Printer	$3,660
Grand Total	$149,320

Table II. Camera, shutter, and lens costs.

Camera / Shutter / Lens	Manufacturer	Part Number	Price	Qty	Ext Price
Sinar P3	Sinar	21-2202	$8,212	1	$8,212
100mm HR	Sinar	25-3186	$6,925	1	$6,925
Sinar m	Sinar	96-0009	$8,315	1	$8,315
Quick Clamping Adapter	Sinar	96-7030	$417	1	$417
LC 100 - Liquid Crystal Shutter	Sinar	97-7010	$2,400	1	$2,400
Sinar m Power Supply	Sinar	96-7070	$287	1	$287
Geared Rail Clamp	Sinar	23-1020	$1,177	1	$1,177
6" Extenstion Rails, Black	Sinar	23-1207	$238	2	$475
Adapter Ring 100/M58	Sinar	23-2304	$105	1	$105
				Total	$28,313

Table III. Digital back costs.

Digital Back	Manufacturer	Part Number	Price	Qty	Ext Price
Sinarback 54H	Sinar	97-6750	$30,225	1	$30,225
Sinar 100 Adapter Kit 2	Sinar	96-7305	$1,181	1	$1,181
				Total	$31,406

Table IV. Camera support costs.

Camera Support	Manufacturer	Part Number	Price	Qty	Ext Price
DSS-ALHPA Stand	Foba	31-0200	$6,820	1	$6,820
ALPHA Gear w/Angle Bracket	Foba	31-0176	$1,613	1	$1,613
ALPHA Accessory Tray	Foba	31-0172	$229	1	$229
				Total	$8,662

Table V. Lighting costs.

Lighting	Manufacturer	Part Number	Price	Qty	Ext Price
Pulso G2 - 1600Ws	Broncolor	12-6000	$1,899	2	$3,797
Grafit A4	Broncolor	10-3025	$8,476	1	$8,476
P70 Reflector	Broncolor	12-0070	$248	2	$497
Senior Light Stand	Broncolor	13-1003	$275	2	$550
				Total	$13,319

Table VI. Computer costs.

Computer	Manufacturer	Part Number	Price	Qty	Ext Price
Apple Dual 2.5 Ghz G5 8GB/500GB/23" LCD	Apple		$8,723	1	$8,723
IBM T221-DG5 22.2 inch QUXGA-W	IBM	9503-DG5	$8,399	1	$8,399
				Total	$17,122

Table VII. File server costs.

File Server	Manufacturer	Part Number	Price	Qty	Ext Price
Apple XRaid 5.6TB RAID (14 x 400GB)	Apple		$13,848	1	$13,848
Apple 2Ghz Xserve G5 / 2GB	Apple		$3,399	1	$3,399
				Total	$17,247

Table VIII. Software costs.

Software	Manufacturer	Part Number	Price	Qty	Ext Price
Matlab 7	Mathworks		$1,900	1	$1,900
Optimization Toolbox 3	Mathworks		$900	1	$900
Image Processing Toolbox 5	Mathworks		$900	1	$900
Signal Processing Toolbox 6	Mathworks		$800	1	$800
Statistics Toolbox 5	Mathworks		$800	1	$800
Photoshop CS2	Adobe		$599	1	$599
CaptureShop 5 - RIT Edition	Sinar		$0	1	$0
ProfileMaker5 Photostudio Eye-One Bundle	GretagMacbeth	35.50.07	$2,995	1	$2,995
				Total	$8,894

Table IX. Color calibration costs.

Color Calibration	Manufacturer	Part Number	Price	Qty	Ext Price
ColorChecker	GretagMacbeth	50105	$74	1	$74
ColorCheckerDC	GretagMacbeth	GMB107	$280	1	$280
Digital ColorChecker SG	GretagMacbeth	50106	$295	1	$295
ColorChecker White Balance	GretagMacbeth	50101	$49	1	$49
Esser TE-221 (IEC 61966-9)	Esser		$500	1	$500
				Total	$1,198

Table X. Filter slider costs.

Filter Slider	Manufacturer	Part Number	Price	Qty	Ext Price
NIR Blocker	Unaxis		$250	2	$500
Schott BG39 Filter Glass (Milled,Cut & Coated)	Schott		$500	1	$500
Schott BG475 Filter Glass (Milled,Cut & Coated)	Schott		$500	1	$500
Additional Cutting/Coating/Glueing	JML Optical		$500	2	$1,000
Custom Two Position Filter Slider	Sinar		$15,000	1	$15,000
BK-7 Sinarback CCD Cover Glass Replacement	Sinar		$2,000	1	$2,000
				Total	$19,500

Table XI. Printer costs.

Printer	Manufacturer	Part Number	Price	Qty	Ext Price
Epson 7600 - Ultrachrome	Epson	C472001UCM	$2,995	1	$2,995
UltraChrome Inkset	Epson	T543(1-7)00	$70	7	$490
Ultrasmooth Fine Art Paper 24" x 50'	Epson	S041782	$175	1	$175
				Total	$3,660

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Summary

Spectral-based imaging facilitates image archives with high colorimetric accuracy and the opportunity for quantitative analysis, in similar fashion to spectral-based analytical techniques common to conversation science. Most commonly, such systems are imaging spectrometers, sampling the visible spectrum at between 10 and 50 nm bandwidth and interval. They are complex, expensive, and require considerable imaging science expertise. This publication describes an alternate approach that results in a practical system, appropriate for museum, libraries, and archives. A professional-grade, color-filter-array digital camera was modified by removing its infrared cover glass and replacing it with clear glass. Two filters, blue-green and yellow, were designed for placement in the optical path sequentially. Design criteria included spectral and colorimetric accuracy, image noise, capture time, ultraviolet and infrared radiation rejection, and fabrication simplicity and cost. The pair of images were registered and corrected for dark noise and spatial inhomogeneities. Using a calibration target of colored samples with known optical properties as a function of wavelength, a transformation was derived that converted camera signals to spectral reflectance factor. Deriving the transformation matrix was based on the Wyszecki hypothesis in which a spectrum can be decomposed into a fundamental stimulus (defining its color) and a metameric black (defining its colorants). The system was

tested using colored targets and an oil painting, *Pot of Geraniums* by Henri Matisse. Comparisons were made with an imaging spectrometer consisting of a monochrome sensor and a liquid-crystal tunable filter and a commercial RGB digital camera. The new, practical system had the highest colorimetric accuracy of the three systems and equivalent spectral accuracy to the 31-band imaging spectrometer.

Introduction

Since 2001, the Munsell Color Science Laboratory has had a research program with the aim of developing spectral-based imaging, archiving, and reproduction of cultural heritage. The program is called Art-SI, standing for Art Spectral Imaging, and can be accessed online at http://www.art-si.org/. Three imaging approaches have been studied: spectral measurement using a monochrome sensor and a liquid-crystal tunable filter (LCTF), spectral estimation using a monochrome sensor and six optimized absorption filters, and spectral estimation using a color-filter array (CFA) sensor and two optimized absorption filters. Berns has summarized each approach and provided an extensive listing of publications [1]. This last approach has the greatest potential for day-to-day usage in a cultural-heritage-institution imaging department such as a museum, archive, or library, principally because it is based on a simple modification of commercially available professional-grade digital cameras and the department's workflow can be streamlined. (We will use the term "museum" for the remainder of this publication.) The purpose of this publication is to describe the approach and present a comparison with both the LCTF system [2] and a color-managed RGB system. Greater details about the comparison can be found in reference 3.

Technical Approach – General Overview

For those active in spectral-based imaging research, it is well understood that a camera should have more than three channels (e.g., RGB) when used to estimate the spectral properties of reflecting objects as a general solution. We have determined that six channels are sufficient for our application [4]. One way to achieve six channels is to use a digital color camera with a color filter array (CFA) sensor and sequentially place two absorption (colored) filters in the optical path. This results in a pair of RGB color images, equivalent to six channels. (Of course, one

could also use an RGB camera with and without a single colored filter [4].) By imaging a calibration target with a number of colored patches (e.g., GretagMacbeth ColorChecker DC or SG), a transformation is derived that converts the six signals to spectral reflectance factor. In our research, spectral reflectance factor ranges between 380 and 730 nm in 10 nm increments with a constant 10 nm bandwidth. When referring to this technique, the term "spectral estimation" rather than "spectral measurement" is used because the system is mathematically underdetermined: six input channels predict 36 output channels.

The general workflow is shown in Figure 1. We have used a Sinarback 54H digital back with Sinar P3 body, Sinaron Digital HR 100mm lens, and Sinar m shutter in our research [5]. The camera was modified by replacing the sensor's blue-green cover glass with a clear cover glass. This extended the spectral sensitivity of the camera into the near infrared. A Sinar liquid crystal shutter was modified to hold the two filters. A pair of Broncolor Pulso G2 Xenon strobes were used to illuminate the object plane.

The camera back had micro-positioning capabilities; the sensor was moved four times to position each color of the Bayer patterned CFA over every pixel's spatial location. This is known as the "four shot" or "four pop" mode and results in full color images without spatial interpolation, but can only be used for static scenes. The four shots were repeated with each filter in front of the lens, resulting in an "eight shot" or "eight pop" mode. Capture was controlled by a modified version of Sinar's CaptureShop software. For each exposure time, the software captured an image with the shutter closed and subtracted this "dark-image" from subsequent exposures. The software also applied a multiplicative spatial correction called the sensor shading reference that compensated for pixel-wise differences in the camera's gain. Both operations were transparent from the user's perspective. The resulting eight-plane image was stored in Sinar's, TIFF based, STI file format.

The remaining image processing steps were implemented using the programming language, Matlab [6]. The next step was to re-assemble each pair of four-planes into a pair of three-plane images. The spectral sensitivity of the Bayer-patterned CCD varied slightly for green

pixels that were adjacent to either red or to blue pixels. For the three-plane image, only the red, blue, and red-adjacent green pixels were used.

The physical movement of the two filters resulted in a registration difference between the pair of three-plane images, typically on the order of ten pixels (about 0.25%). Using the public domain software library, ITK [7], and assuming that the images varied only in translation, the images were registered by applying a transformation calculated from a small user-defined region of the image. (A more robust approach is a future activity.)

A multiplicative spatial correction was applied to compensate for spatially non-uniform lighting, commonly used to accentuate surface topography such as impasto. The correction was based on an image of a neutral background, shot under the same conditions as the object.

A transformation matrix was derived from a calibration target of known spectral reflectance factors. The transformation matrix was used to convert the six-channel image to a 36-channel image, resulting in an estimate of the object's spectral reflectance factor as a function of position. The calibration procedure is described in the next section.

For most applications, the spectral image was rendered for a specific CIE illuminant and observer using conventional colorimetric calculations. For the case of an ICC color-managed workflow, this was CIE Illuminant D50 and the 1931 standard observer. The rendering produced a digital master saved as a 16-bit CIELAB TIFF file with linear encoding with respect to CIELAB (similar to reciprocal gamma encoding of 1/2.4).

For archiving purposes, we anticipate storing the registered spatially-corrected six-channel images along with corresponding calibration meta-data using the DNG file format.

Technical Approach – Details

The multi-filter approach [8] was first demonstrated using an IBM Pro/3000 digital camera based on a monochrome linear CCD with colorimetric filters. For the current Kodak KAF 22000CE

CCD sensor, filters had to be defined and fabricated. An optimization was performed to select filters from among the Schott filter glass catalog. The optimization considered spectral and colorimetric accuracy, image noise, capture time, and fabrication simplicity and cost [9 – 11]. There were a number of different filter pairs with similar performance. We selected a pair in which one of the filters resulted in spectral sensitivities similar to the sensor with its original blue-green cover glass. Thus, the camera could also be used in the usual fashion as a color-managed RGB digital camera. The final filters are listed in Table 1 and plotted in Figure 2. Each was a "sandwich" of an absorption filter and a visible bandpass filter (i.e., a UV and NIR blocking filter). The bandpass filter transmitted radiation between 380 and 750 nm. The surface of each filter facing the sensor was anti-reflection coated to minimize inter-reflections between the lens filter and CCD cover glass. The spectral sensitivities of the CFA sensor are plotted in Figure 3. In the visible region, there are the expected three peaks at red, green, and blue wavelengths. The red channel has sensitivity in the red and near infrared regions while the blue and green channels have sensitivity in the near infrared. The effect of placing each optimized filter in the optical path is plotted in Figure 4. The blue-green filter predominantly affects the red channel sensitivity by defining the wavelength of peak sensitivity and bandwidth. The yellow filter predominantly affects the blue channel sensitivity by narrowing bandwidth. The visible bandpass filter, common to both filter sandwiches, limits spectral sensitivity to the visible region, critical when correlating with the human visual system. Based on Figure 4, it appears that the two filters have a minimal affect on increasing spectral information beyond that normally captured with a CFA sensor. As described above, spectral reflectance factor is estimated by a linear calibration transformation. This is equivalent to creating new spectral sensitivities by weighted addition or subtraction of the spectral sensitivities plotted in Figure 4. As an example, in Figure 5, the yellow-filtered blue channel was subtracted from the blue-green-filtered blue channel and blue-green filtered red channel was subtracted from the yellow-filtered red channel, plotted as dashed lines, along with the blue-green filtered spectral sensitivities, plotted as solid lines. It is observed that the visible spectrum is sampled in five discrete locations. The two-filter approach along with the calibration transformation has enabled the increase in sampling number.

Typically, the matrix coefficients are optimized to minimize either spectral or colorimetric error. We have developed a technique where both errors were minimized [12],

based on the Wyszecki hypothesis that a stimulus can be decomposed into a fundamental stimulus and a metameric black [13]. Our approach was similar to the Fairman technique of transforming a parameric pair into a metameric pair [14]. Conceptually, the fundamental stimulus corresponds to the spectral information that our visual system processes. The metameric black corresponds to the spectral information that is not processed; hence it has no color and it is black. The metameric black defines the spectral characteristics that depend on the specific colorants used to provide selective absorption. Accurate estimation of a fundamental stimulus results in high colorimetric accuracy. Accurate estimation of a metameric black results in high spectral accuracy.

Previously [12], the colorimetric transformation consisted of a nonlinear stage that accounted for stray light, differences in geometry between the reference spectrophotometer and camera system, and any non-linearities in the camera signal processing. Experimentally, the transfer functions were nearly linear with a small offset. This allowed the transformation to be simplified as shown in Eqs. (1) – (5):

$$\mathbf{M}_{pinv} = \mathbf{R}_{\text{Reference}}\,\text{pinv}\left(\mathbf{D}_{\text{Reference}}\right) \tag{1}$$

$$\mathbf{A} = \frac{100}{\mathbf{S}'\overline{\mathbf{y}}}\,\text{diag}\left(\mathbf{S}\right)\overline{\mathbf{xyz}} \tag{2}$$

$$\mathbf{T}_{\Delta E_{00}} = \text{f}_{NonLinOpt}\left(\mathbf{R}_{\text{Reference}}, \mathbf{A}, \mathbf{D}_{\text{Reference}}\right), \text{ where } \mathbf{T}_{\Delta E_{00}} \text{ minimizes } \left[\Delta \text{E}_{00}\left(\mathbf{T}_{\Delta E_{00}}\mathbf{D}, \mathbf{A}'\mathbf{R}_{\text{Reference}}\right)\right] \tag{3}$$

$$\mathbf{M}_{\Delta E_{00}} = \mathbf{A}\left(\mathbf{A}'\mathbf{A}\right)^{-1}\mathbf{T}_{\Delta E_{00}} + \left(\mathbf{I} - \mathbf{A}\left(\mathbf{A}'\mathbf{A}\right)^{-1}\mathbf{A}'\right)\mathbf{M}_{pinv} \tag{4}$$

$$\hat{\mathbf{R}}_{\Delta E_{00}} = \mathbf{M}_{\Delta E_{00}}\mathbf{D} \tag{5}$$

where n is the number of wavelengths, i is the number of camera channels, and j is the number of reference color patches. Matrix $\mathbf{M}_{pinv}$ is a $[n \times (i+1)]$ transformation matrix from digital counts to spectral reflectance factor computed from $\mathbf{R}_{\text{Reference}}$, a $[n \times j]$ matrix containing the calibration target reference spectrophotometric measurements ranging from zero to unity and $\mathbf{D}_{\text{Reference}}$ is an $[(i+1) \times j]$ camera digital count matrix with the last row set to unity (homogenous coordinates). The operation *pinv* represents the Moore-Penrose singular-value decomposition-based pseudoinverse function in Matlab [6]. Matrix $\mathbf{A}$ is a $[n \times 3]$ matrix of tristimulus weights

computed from **S**, a [$n \times 1$] vector of the spectral power distribution of the reference light source, $\bar{\mathbf{y}}$, a [$n \times 1$] vector of the reference luminance color matching function, and $\overline{\mathbf{xyz}}$, a [n $\times$ 3] matrix of the reference color matching functions. Matrix $\mathbf{T}_{\Delta E_{00}}$ is a [$3 \times (i+1)$] transformation matrix from digital counts to tristimulus values fit using nonlinear optimization described below. Matrix $\mathbf{M}_{\Delta E_{00}}$ [$n \times (i+1)$] is a transformation matrix from digital counts to spectral reflectance factor computed from **A**, $\mathbf{T}_{\Delta E_{00}}$, **I**, an [$n \times n$] identity matrix, and $\mathbf{M}_{\Delta E_{00}}$. Vector $\hat{\mathbf{R}}_{\Delta E_{00}}$ [$n \times 1$] is the imaging-based estimated spectral reflectance factors; it is the product of $\mathbf{M}_{\Delta E_{00}}$ and **D**, a [$(i+1) \times 1$] vector of camera digital counts with the last element set to unity. In Eq. (3), $\mathbf{T}_{\Delta E_{00}}$ was optimized using a two stage process. First, nonlinear constrained optimization was used to minimize the average ΔE_{00} compared with the reference tristimulus values using a starting value for $\mathbf{T}_{\Delta E_{00}}$ of $\mathbf{A'R}_{\text{Reference}}\,\text{pinv}(\mathbf{D}_{\text{Reference}})$. These optimized matrix coefficients were used as starting values for a second nonlinear constrained optimization that minimized $(\text{Mean}(\Delta E_{00})/\text{Mean}(\Delta E_{00})_{\text{Optimization 1}} + \max(\Delta E_{00})/\max(\Delta E_{00})_{\text{Optimization 1}})$. Both optimizations were subject to the constraint that the coefficients not change more than ±50% from their starting values. In Eq. (4), the left-most term of the right-hand side of the equation, $\mathbf{A}\left(\mathbf{A'A}\right)^{-1}\mathbf{T}_{\Delta E_{00}}$, estimated the fundamental stimulus and the right-most term, $\left(\mathbf{I}-\mathbf{A}\left(\mathbf{A'A}\right)^{-1}\mathbf{A'}\right)\mathbf{M}_{pinv}$, estimated the metameric black. The final linear calibration transformation is shown in Eq. (5). As a linear operation, it was implemented very efficiently.

Experimental Verification – Targets

The MCSL-Sinar system was tested in the Imaging Department of the National Gallery of Art, Washington DC (NGA). It was compared with two other systems. The first was our spectral measurement system consisting of a Quantix monochrome sensor coupled with a Cambridge Research Institute liquid crystal tunable filter (LCTF), evaluated at NGA previously [2, 15]. The system used diffuse tungsten illumination. The calibration transformation was based on a GretagMacbeth ColorChecker DC and a custom target of blue acrylic artist paints, described below. The second system was a stock Sinarback 54M with a P3 body and a 100mm lens with

integral shutter. This system was used routinely at NGA. The calibration target was a GretagMacbeth ColorChecker SG. Commercial software was used to create an ICC camera profile for the NGA system. The MCSL-Sinar and NGA-Sinar systems used the identical lighting set-up, a pair of Broncolor Xenon strobes, positioned at approximately a 70° angle from the surface normal on either side of the artwork. One side had about twice the irradiance. This resulted in a quite collimated, raking illumination.

For this experiment, four targets were evaluated, described in Table 2. The GretagMacbeth targets were available commercially. The Gamblin target was produced by mixing each of the 31 conservation colors with titanium white at two different concentrations and applying them to canvas board using a brush. The Blues target was made by mixing Liquitex Artist Acrylic ultramarine, cobalt, Prussian, and phthalocyanine blue paints and titanium white in various proportions in order to create a target with a large range of spectral characteristics. These paints were also applied to a canvas board using a brush. The experiment consisted of imaging the four targets followed by processing as described in Figure 1 and Eqs. (1) – (5). The targets were used as either calibration or verification targets.

The colorimetric performance of the three systems is shown in Table 3. Both ΔE_{00} and ΔE^*_{ab} are shown, the former metric having better correlation with subjective evaluations of adjacent uniform color fields [16] and the latter having better correlation with images [17]. Experientially, the 90^{th} percentile results are a better indicator of performance than the maximum error, particularly for actual experiments (rather than computational analyses).

The Best Case corresponds to the MCSL-Sinar system where the same target was used for calibration and verification. This provides a sense of the best mean performance that can be achieved using the MCSL-Sinar system and the linear signal processing workflow as described. These results are excellent indicating that the multi-filter system is capable of high color accuracy. The small differences in performance between matched calibration and verification targets (Best Case) and independent calibration and verification targets (MCSL-Sinar) indicate that the choice of calibration target is important. Although progress has been made [18, 19],

research is still required to develop an improved calibration target for imaging paintings. Guiding principles should include those defined for exemplifying color-order systems [20].

The color management at NGA was very good. The listed results are typical of a well color-managed area-array color sensor camera system [21, 22]. The modifications to the Sinar camera resulted in marked improvement, particularly for the Gamblin target that consisted of typical artist pigments used in paintings. There was nearly a threefold improvement, though some of this improvement may be attributed to the Blues calibration target, which better represents blue artist materials than the ColorChecker SG. An analysis of variance followed by a multiple comparison test based on Turkey simultaneous confidence intervals using the studentized range distribution was performed [6] on the CIEDE2000 values to assess statistical significance. For all the targets, the MCSL-Sinar system was superior to the NGA system at an α of 0.01.

On average, the MCSL-Sinar system had slightly superior colorimetric performance to the Quantix-LCTF system. For the ColorChecker DC and Gamblin targets, the MCSL-Sinar system was superior at an α of 0.01. For the ColorChecker and Blues targets, the two systems were not significantly different. This is an important result: A six-channel camera had the average colorimetric accuracy of a 31-channel camera. The maximum and 90^{th} percentile errors for the Quantix-LCTF system were smaller for the Blue Pigments and Gamblin Conservation Colors targets. The improved average colorimetric performance was a result of the more complex signal processing combining colorimetric and spectral optimization. The colorimetric optimization used nonlinear optimization since color differences are nonlinearly related to incident radiation. This nonlinear optimization was impractical for the Quantix-LCTF since 250,000 independent data points were used to estimate 1,116 coefficients (31 x 36 matrix). Nonlinear optimization would have been extremely time consuming and convergence to a global minimum highly problematic. Therefore, the Quantix-LCTF calibration only optimized spectral-estimation accuracy using linear optimization.

The spectral performance of the Quantix-LCTF and MCSL-Sinar systems are listed in Table 4. A metameric index was calculated to provide a performance metric in color-difference

units. This index is a ΔE_{00} value for CIE Illuminant A following a slight spectral adjustment [14] such that for CIE Illuminant D65, the colorimetric data are identical, that is, a ΔE_{00} of zero. [The spectral adjustment is the Fairman parameric correction, shown in Eq. (4).] The spectral root-mean-square (RMS) error over the wavelength range of 380-730 nm was also calculated. The Quantix-LCTF system had higher spectral accuracy than the MCSL-Sinar system. For the ColorChecker DC, the ColorChecker, and the Blues targets, the Quantix-LCTF system was superior at an α of 0.01 (based on evaluating RMS error); for the Gamblin target, there was not a statistically significant difference. The superior performance was the expected result since the Quantix-LCTF system was a true spectral device whereas the MCSL-Sinar was an abridged device. What was unexpected was that the performance of the MCSL-Sinar system was so close to the Quantix-LCTF system and for the Gamblin target, the two systems were equivalent statistically. Furthermore, the Best Case results and the Quantix-LCTF system were not significantly different except for the Blues target. To be fair, it needs to be pointed out that much more effort had been put into development of the MCSL-Sinar system. Once we achieved an acceptable result for the spectral camera, we began looking at more practical approaches. It is likely that if we had selected the Quantix-LCTF system as the recommended system, better performance would be reported herein.

The GretagMacbeth ColorChecker Color Rendition Chart has become a *de facto* imaging standard. The spectral estimation accuracy of this target for the MCSL-Sinar and Quantix-LCTF systems are shown in Figure 6. The average spectral difference as a function of wavelength is plotted as the blue solid line. The Quantix-LCTF system had a nearly flat curve quite close to zero, the desired result whereas the MCSL-Sinar system had a strong undulation. Plots of the neutral colors would show excessive undulation. This is a common result for such an abridged spectrometer. We have performed some preliminary research to address this problem including pigment mapping [23] and treating the camera system as a conventional spectrophotometer [24].

At every wavelength, a scatter plot could be made comparing the spectrophotometer and camera system and a line fit to these data. A correlation coefficient of the line fit would indicate the amount of scatter. In order to have a number with similar magnitude to the spectral differences, the correlation coefficient, ranging between zero and unity, was subtracted from

unity. Perfect correlation would yield zero. These values as a function of wavelength are plotted in Figure 6 as the dashed red line. For both systems, large scatter occurred for short wavelengths. This was caused largely by the calibration targets containing titanium dioxide white. It has very low reflectance in this wavelength range and the spectral variation of the target patches was very small. This resulted in large uncertainty when estimating these wavelengths using each camera system. A second reason concerned the low quantum efficiency of CCD sensors in this wavelength range, also increasing uncertainty.

Experimental Verification – Henri Matisse, *Pot of Geraniums*

When the Quantix-LCTF system was tested at NGA, three paintings were imaged: Alvise Vivarini, *Saint Jerome Reading*; Alexej von Jawlensky, *Murnau*; and Henri Matisse, *Pot of Geraniums*; all among the permanent collection of NGA. The Matisse proved to be the most challenging [2, 15], having the widest range of pigments and spectral properties. This painting was again imaged using the MCSL-Sinar and NGA-Sinar systems. A GretagMacbeth EyeOne had been used to measure 43 positions on the painting. The painting and the measurement positions are shown in reference 2.

Preliminary evaluations were performed where each test target was used to derive the calibration transformation converting camera signals to spectral reflectance factor and CIELAB for the MCSL-Sinar system. As described above, the results were affected by the choice of calibration target. Not surprising, the Gamblin target was the most successful. There were two reasons. First, the spectral properties of this target span the spectral properties of the painting. Second, this target was painted on canvas board, resulting in similar surface characteristics to the painting. Because the NGA lighting was so directional, having similar surface properties between the calibration target and the painting helped improve spectral and colorimetric accuracy. This second reason was more important than the first, as evinced by the Gamblin target having superior performance to the combination of the ColorChecker DC and Blues targets.

The National Gallery of Art's imaging workflow included visual editing where local and global color corrections were made using Adobe Photoshop to improve the color-matching accuracy between a work of art illuminated with high color rendering daylight-fluorescent

sources (nominal CCT of 5000 K) and the image rendered on a color-managed CRT display [3]. Their digital master image files included these visual adjustments.

The colorimetric accuracy of *Pot of Geraniums* is summarized in Table 5. The Quantix-LCTF system had the best colorimetric performance on average, likely a result of using diffuse rather than directional illumination. This underscores how lighting for aesthetic purposes may not result in optimal images for scientific purposes. The MCSL-Sinar system had slightly lower average accuracy than the Quantix-LCTF system. Given the aesthetic-oriented lighting, this was an excellent result. The color-managed NGA-Sinar system image before visual editing also had good performance given its intrinsic limitations as a three-channel RGB device. Statistically, these three systems were not significantly different from one another. The uncertainty in comparing *in-situ* measurements with spectral imaging increased variability [2] compared with color targets; consequently, the performance differences were not statistically significant.

A disappointing, although common [21, 22], result was that the visual editing decreased accuracy dramatically. Average ΔE_{00} increased by over 50%. This digital master was statistically significantly worse than the other three images at an α of 0.01. Some of the possible reasons for the increased error might have been a poorly color-managed display, unmatched white points in terms of chromaticity and luminance resulting in light and chromatic adaptation differences between the viewing illuminant and display, differences in lighting geometry between the imaging system (directional Xenon strobe) and the viewing environment (overhead fluorescent daylight), differences in image size, and observer metamerism. The color changes were reductions in chroma and lightness.

The spectral performance is shown in Table 6 and Figures 7 and 8. The MCSL-Sinar system had reasonable performance, well capturing the spectral characteristics of the painting throughout the majority of the sampled spectrum. Similar to the ColorChecker results, both systems had poor performance at short wavelengths, as seen in Figure 8. The average RMS difference as a function of wavelength was centered about zero for the MCSL-Sinar systen whereas for the Quantix-LCTF system, there was a systematic under-prediction in spectral reflectance factor. This was a result of geometric differences between the camera taking

illumination geometry, the calibration target spectrophotometric measurement geometry, and differences in gloss between the calibration targets and the painting. An interesting result was that the correlation spectra were similar in shape for both systems. The spectral performances were not statistically significantly different.

Conclusions

A practical spectral-based imaging system has been developed in which a color filter array (CFA) digital camera was combined with two absorption filters. By taking two sequential images, one with each filter, and deriving a linear transformation matrix using a target of colored patches with reference spectral reflectance factor values, spectral images were estimated. The performance was evaluated for test targets and an oil painting, Henri Matisse's *Pot of Geraniums*. This system had spectral and colorimetric performance that was equivalent to a true spectral imaging system consisting of a monochrome camera and liquid-crystal tunable filter.

The main advantage of this new system is that any CFA professional-grade camera system can be used, following a simple modification of replacing the detector cover glass and the addition of a filter slider, or wheel, or holder (i.e., changing filters manually). This means that scientific imaging of the visible spectrum can be the responsibility of an imaging department rather than a highly specialized instrument requiring a conservation scientist well versed in color and imaging science.

Because the system does not have a permanent infrared cut-off filter, it can also be used for infrared reflectometry; the CFA has spectral sensitivity over a wavelength range similar to IR film. Using an appropriate visible-spectrum cut-off or bandpass filter, the camera can be used as a conventional RGB camera, a spectral camera, or an NIR camera.

Future research will focus on imaging and spectrophotometric geometry considerations, improving the spectral accuracy for neutral samples, an improved calibration target, and an Adobe Photoshop implementation of the Matlab software.

Acknowledgements

The authors would like to thank the National Gallery of Art, Washington, D.C., the Museum of Modern Art, New York, the Andrew W. Mellon Foundation, and the Institute of Museum and Library Services for their financial support of the Art Spectral Imaging (Art-SI) Project. We also acknowledge the assistance of the Division of Imaging and Photographic Services and the Division of Conservation at the National Gallery of Art.

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Tables

Table 1. Filter specifications for the optimized filters.

Description	**Filter 1 (Blue-Green)**	**Filter 2 (Yellow)**
Layer 1 (1.1 mm Thickness)	UnAxis Calflex X	UnAxis Calflex X
	Optical Cement	*Optical Cement*
Layer 2 (0.75mm Thickness)	Schott BG39	Schott GG475
	Anti-Reflection Coating	*Anti-Reflection Coating*

Table 2. Test targets used for calibration and verification.

Target	Abbreviation	Number of Samples
GretagMacbeth ColorChecker Color Rendition Chart	ColorChecker or CC	24
GretagMacbeth ColorChecker DC (Digital Camera)	ColorChecker DC or CCDC	240* *The central white square was treated as four samples.
Gamblin Conservation Colors mixed with titanium white	Gamblin	63
Blue acrylic Liquitex paints mixed with titanium white	Blue Pigments or Blues	56

Table 3. Colorimetric performance summary for the three camera systems and a best-case computation where the same target was used for both calibration and verification.

	Matched Calibration and Verification		ColorChecker DC and Blues Calibration		ColorChecker DC and Blues Calibration		ColorChecker SG Calibration	
	Best Case MCSL-Sinar		**Quantix-LCTF**		**MCSL-Sinar**		**NGA-Sinar**	
	ΔE_{00}	ΔE^*_{ab}	ΔE_{00}	ΔE^*_{ab}	ΔE_{00}	ΔE^*_{ab}	ΔE_{00}	ΔE^*_{ab}
ColorChecker DC								
Average	0.7	1.2	1.0	1.5	0.8	1.2	2.7	4.2
Maximum	5.3	15.2	5.4	6.7	4.1	13.8	10.1	33.1
Std. Dev.	0.6	1.4	0.8	1.3	0.5	1.3	1.3	3.1
90Prctile	1.3	2.3	2.2	3.1	1.3	2.3	4.2	7.4
ColorChecker								
Average	0.8	1.3	1.4	2.1	1.1	1.8	2.0	3.3
Maximum	2.2	4.9	4.8	7.8	2.4	5.5	5.0	8.1
Std. Dev.	0.6	1.2	0.9	1.4	0.6	1.3	1.2	2.2
90Prctile	1.5	3.0	2.6	3.1	1.9	3.6	3.6	7.3
Blue Pigments								
Average	0.6	1.1	1.4	2.1	1.3	2.6	4.0	6.8
Maximum	1.7	4.3	4.4	6.1	4.3	7.5	7.0	14.0
Std. Dev.	0.4	0.9	1.0	1.5	1.1	1.8	1.5	2.5
90Prctile	1.3	2.2	2.9	4.8	3.1	5.4	6.0	9.8
Gamblin Pigments								
Average	0.8	1.4	1.7	2.9	1.1	1.9	2.9	5.1
Maximum	2.6	4.6	6.9	11.9	2.3	4.9	6.4	14.1
Std. Dev.	0.4	0.9	1.2	2.3	0.4	1.1	1.4	3.0
90Prctile	1.3	2.8	2.9	5.7	1.6	3.5	4.9	8.5

Table 4. Spectral performance for the two RIT systems and a best-case computation where the same target was used for both calibration and verification.

	Matched Calibration and Verification		ColorChecker DC and Blues Calibration		ColorChecker DC and Blues Calibration	
	Best Case MCSL-Sinar		Quantix-LCTF		MCSL-Sinar	
	Metameric Index (D65→A) (ΔE_{00})	Spectral RMS (%)	Metameric Index (D65→A) (ΔE_{00})	Spectral RMS (%)	Metameric Index (D65→A) (ΔE_{00})	Spectral RMS (%)
ColorChecker DC						
Average	0.4	1.3	0.3	1.2	0.4	1.4
Maximum	3.8	3.9	3.0	9.4	3.1	3.8
Std. Dev.	0.4	0.6	0.4	0.8	0.5	0.7
90Prctile	0.9	2.2	0.9	1.9	0.8	2.2
ColorChecker						
Average	0.4	1.3	0.2	1.5	0.6	2.2
Maximum	1.6	2.9	0.7	3.6	1.6	4.1
Std. Dev.	0.4	0.6	0.2	0.7	0.5	0.9
90Prctile	0.8	2.1	0.5	2.6	1.4	3.4
Blue Pigments						
Average	0.2	1.0	0.3	1.4	0.3	1.8
Maximum	0.7	2.2	1.2	3.1	1.0	3.4
Std. Dev.	0.2	0.5	0.3	0.6	0.3	0.7
90Prctile	0.5	1.7	0.8	2.2	0.8	2.8
Gamblin Pigments						
Average	0.3	1.7	0.3	2.0	0.3	2.4
Maximum	1.4	3.5	1.1	5.3	1.4	5.5
Std. Dev.	0.3	0.8	0.3	1.0	0.3	1.3
90Prctile	0.5	2.8	0.8	3.3	0.6	4.2

Table 5. Colorimetric performance summary for the three camera systems for Pot of Geraniums.

	ColorChecker DC and Blues Calibration		Gamblin Conservation Colors Calibration		ColorChecker SG Calibration		ColorChecker SG Calibration and Visual Editing	
	Quantix-LCTF Digital Master		**MCSL-Sinar Digital Master**		**NGA-Sinar ICC Color Managed**		**NGA-Sinar Digital Master**	
	ΔE_{00}	ΔE^*_{ab}	ΔE_{00}	ΔE^*_{ab}	ΔE_{00}	ΔE^*_{ab}	ΔE_{00}	ΔE^*_{ab}
Average	2.3	3.3	2.7	3.7	3.5	4.8	5.8	7.4
Maximum	9.6	12.4	11.7	14.3	12.2	14.2	13.0	16.1
Std. Dev.	1.9	2.4	2.2	2.8	2.2	2.9	2.1	3.0
90Prctile	4.3	6.0	4.6	7.5	6.4	9.3	8.6	10.9

Table 6. Spectral performance summary for the two RIT camera systems for Pot of Geraniums.

	ColorChecker DC and Blues Calibration		Gamblin Conservation Colors Calibration	
	Quantix-LCTF Digital Master		**MCSL-Sinar Digital Master**	
	MI (D65→A)	sRMS	MI (D65→A)	sRMS
Average	0.3	0.0	0.6	0.0
Maximum	2.2	0.1	1.7	0.1
Std. Dev.	0.4	0.0	0.4	0.0
90Prctile	0.6	0.0	1.2	0.0

Figures

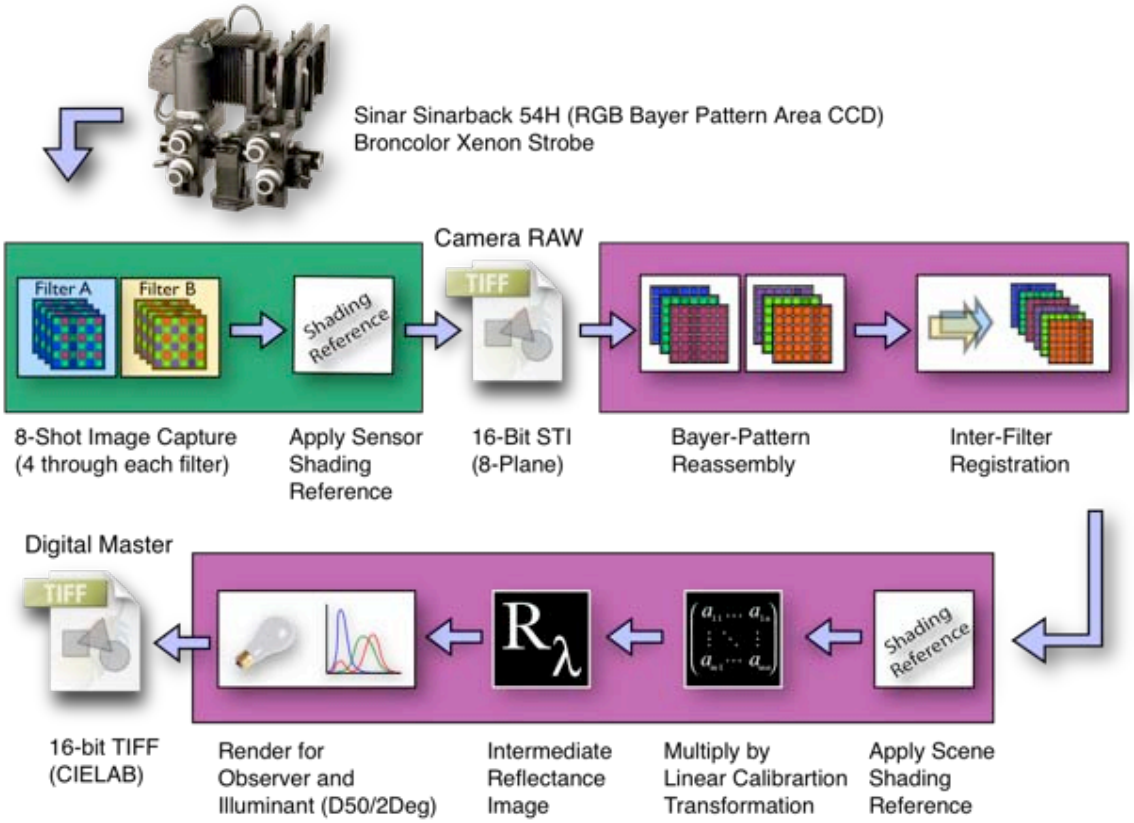


Figure 1. RIT's digital workflow. Areas in green are camera software processing. Areas in pink are RIT software processing.

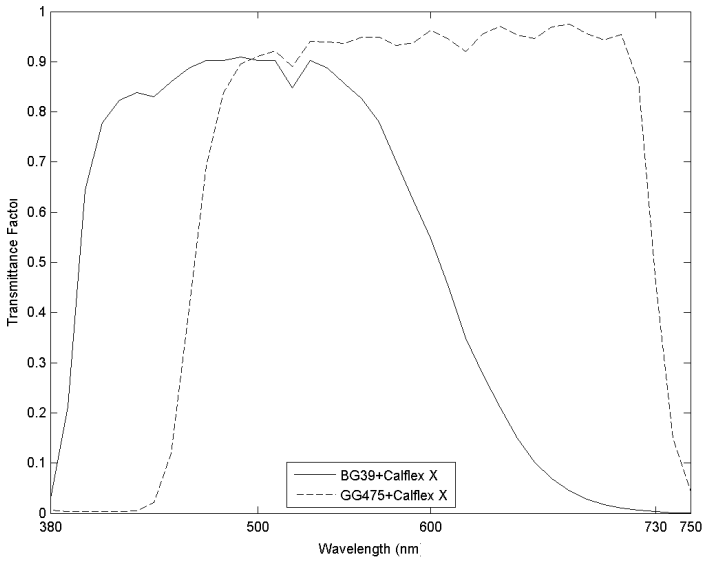


Figure 2. Spectral transmittance of optimized filters described in Table 1.

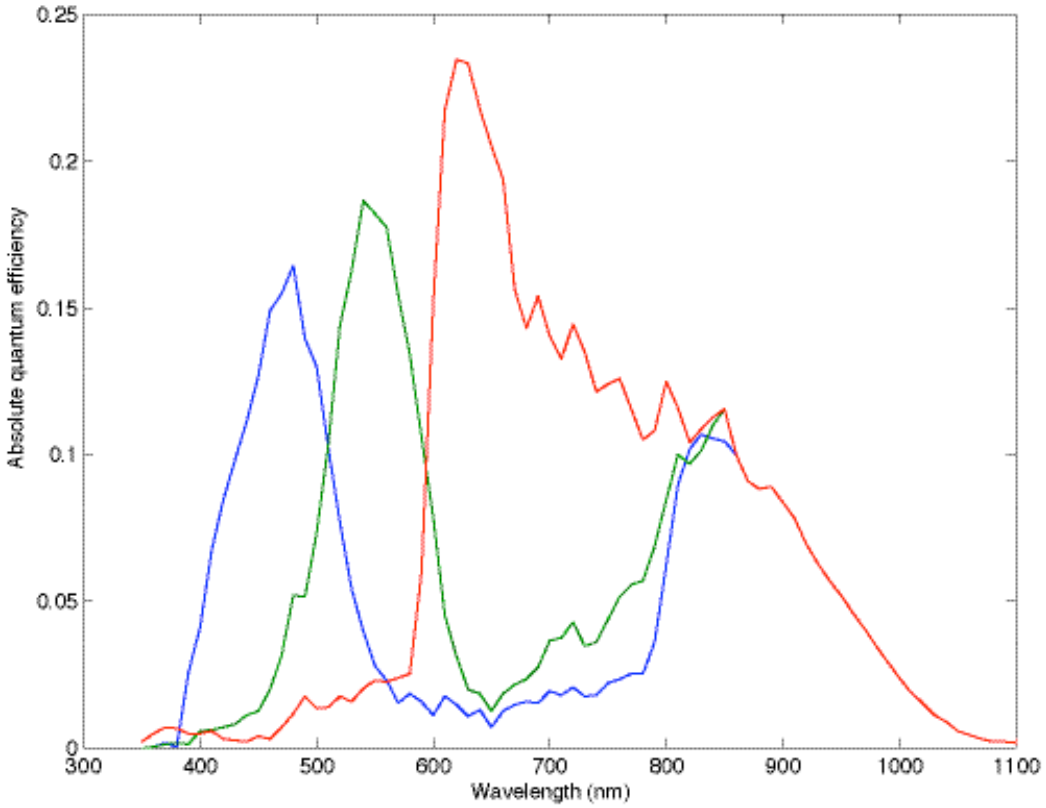


Figure 3. Absolute quantum efficiency (spectral sensitivity) of the Kodak KAF 22000CE color filter array (data provided by the Eastman Kodak Company).

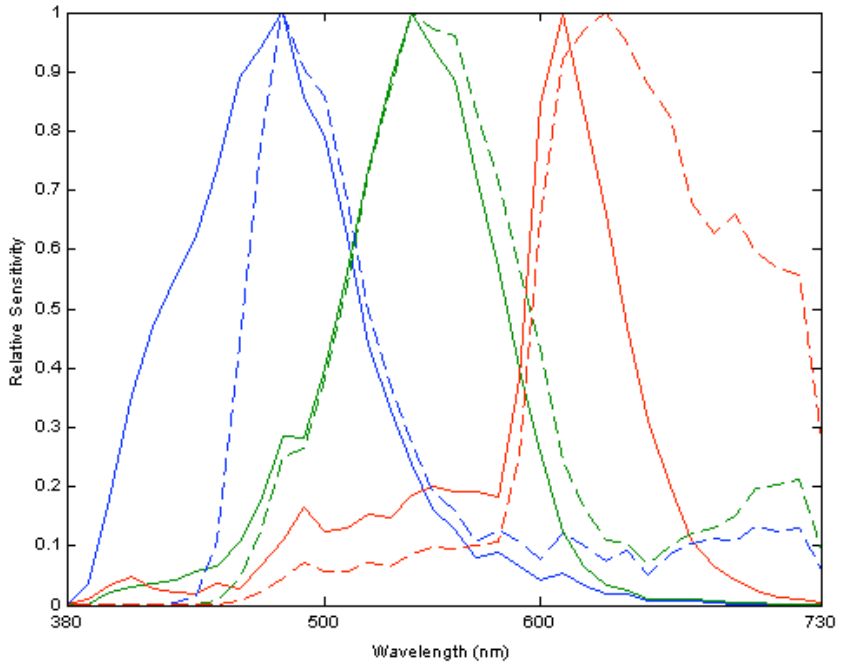


Figure 4. Normalized (to peak height) spectral sensitivities of the Kodak KAF 22000CE color filter array with each optimized filter in the optical path. Solid lines represent the blue-green filter sandwich and the dashed lines represent the yellow filter sandwich. (The detector cover glass and lens spectral transmittances are not included.)

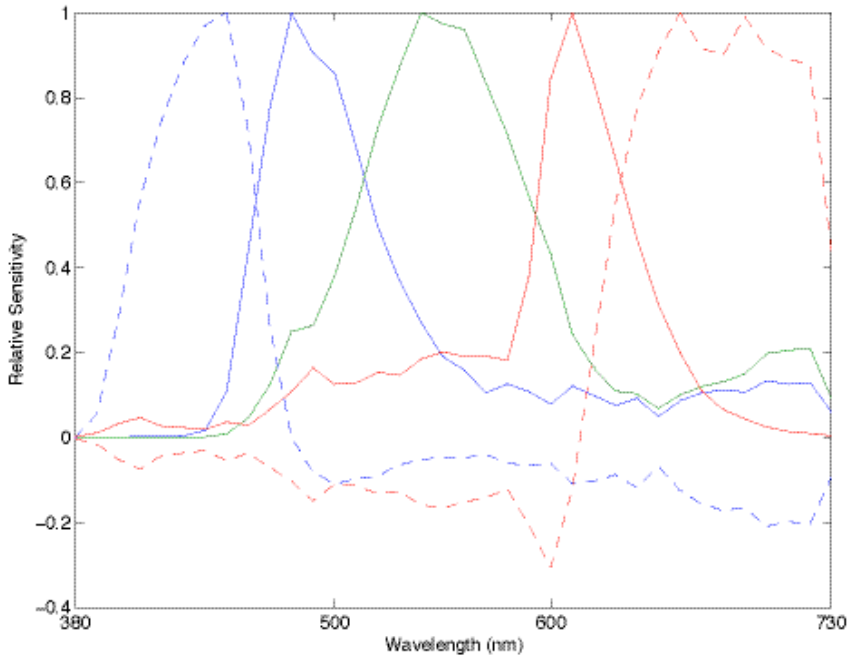


Figure 5. Normalized (to peak height) spectral sensitivities of the Kodak KAF 22000CE color filter array filtered with the blue-green filter sandwich (solid lines), the yellow-filtered blue channel subtracted from the blue-green-filtered blue channel (dashed blue line), and the blue-green filtered red channel subtracted from the yellow-filtered red channel (dashed red line).

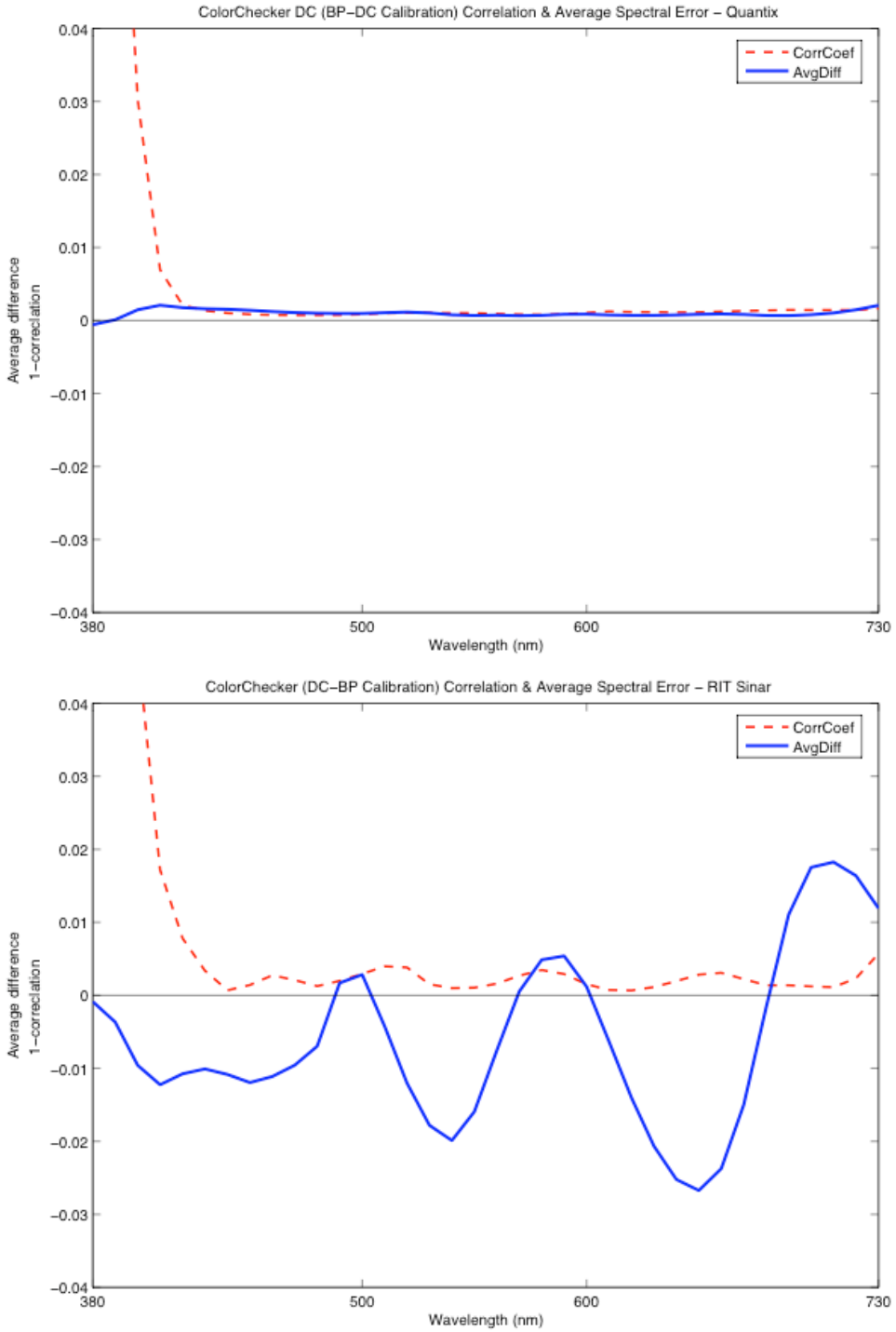


Figure 6. GretagMacbeth ColorChecker average spectral difference (solid line), $R_{image,\lambda} - R_{small\_aperture,\lambda}$, and one minus the correlation coefficient (dashed line) for the Quantix-LCTF (top) and MCSL-Sinar (bottom) systems. .

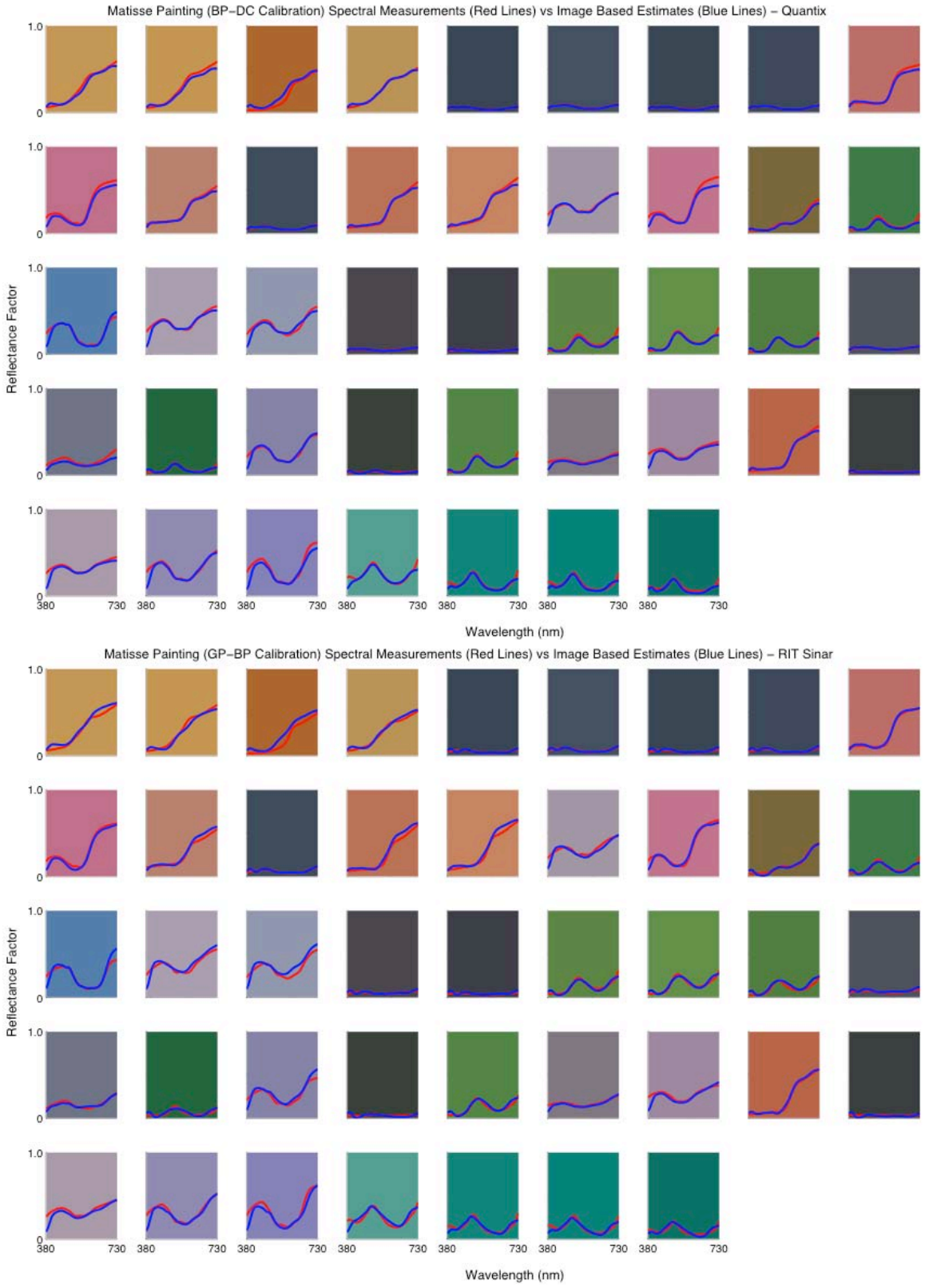

Matisse Painting (BP–DC Calibration) Spectral Measurements (Red Lines) vs Image Based Estimates (Blue Lines) – Quantix
Reflectance Factor
1.0
0
380
730
Wavelength (nm)
Matisse Painting (GP–BP Calibration) Spectral Measurements (Red Lines) vs Image Based Estimates (Blue Lines) – RIT Sinar
Reflectance Factor
Wavelength (nm)

Figure 7. Spectral comparison between reference spectrophotometer (red) and imaging system (blue). Top: Quantix-LCTF; bottom: MCSL-Sinar.

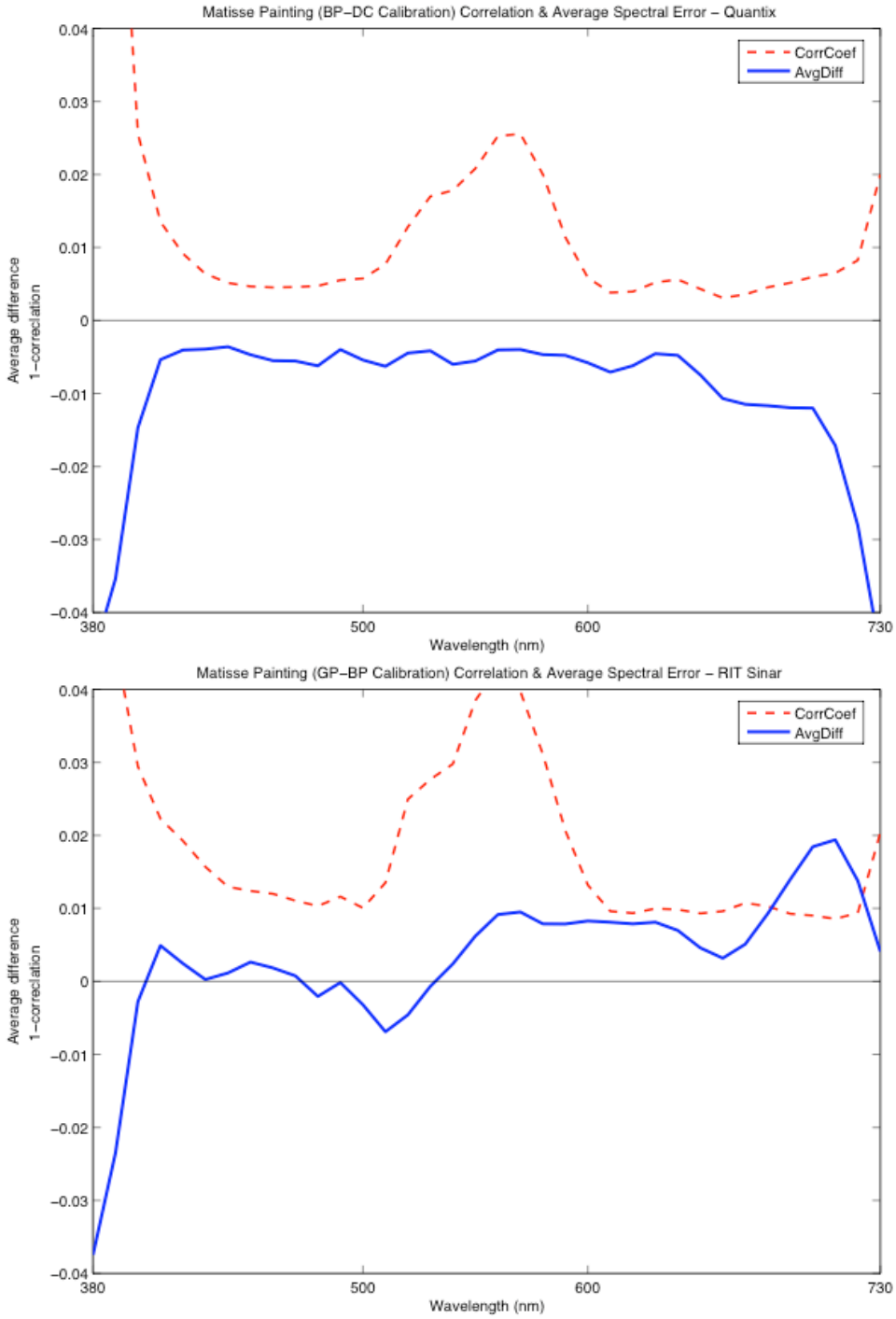


Figure 8. Pot of Geranium's average spectral difference (solid line), $R_{image,\lambda} - R_{small\_aperture,\lambda}$, and one minus the correlation coefficient (dashed line) for the Quantix-LCTF (top) and MCSL-Sinar (bottom) systems.

Other Figure, may or may not be used

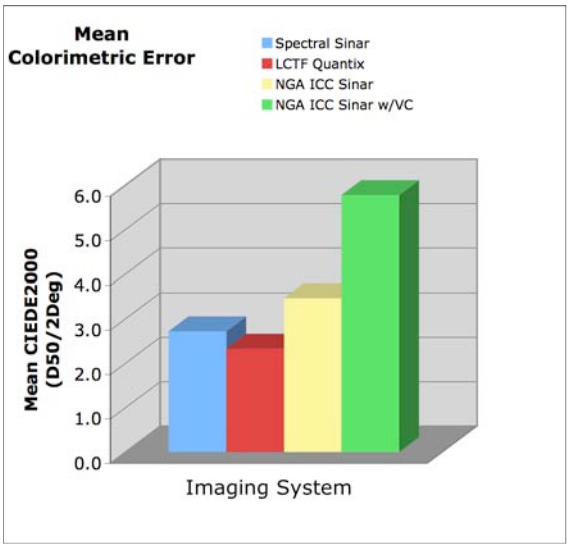


Figure 27. Average ΔE_{00} colorimetric error for each listed imaging system. Blue: the MCSL-Sinar system; red: the Quantix-LCTF system; yellow: the color-managed NGA-Sinar system; green: the digital master (following visual editing) NGA-Sinar system.

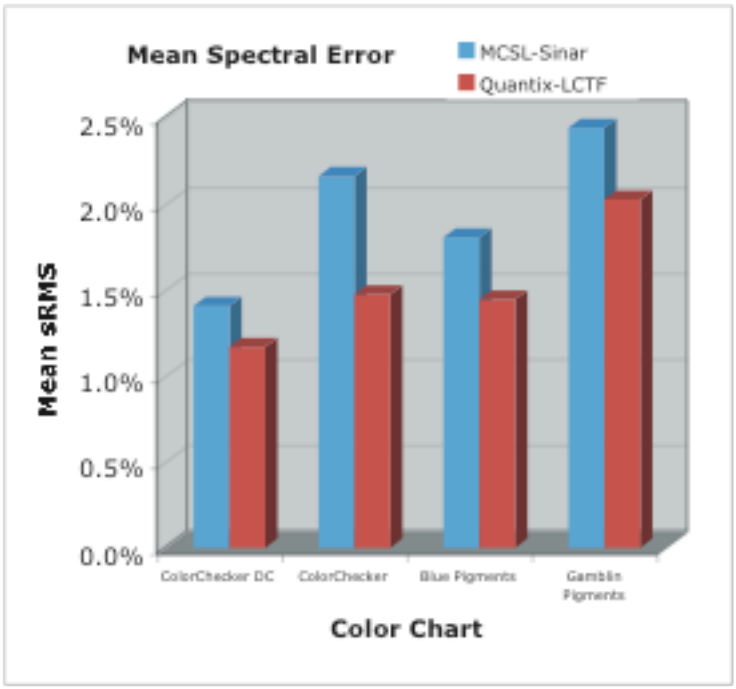
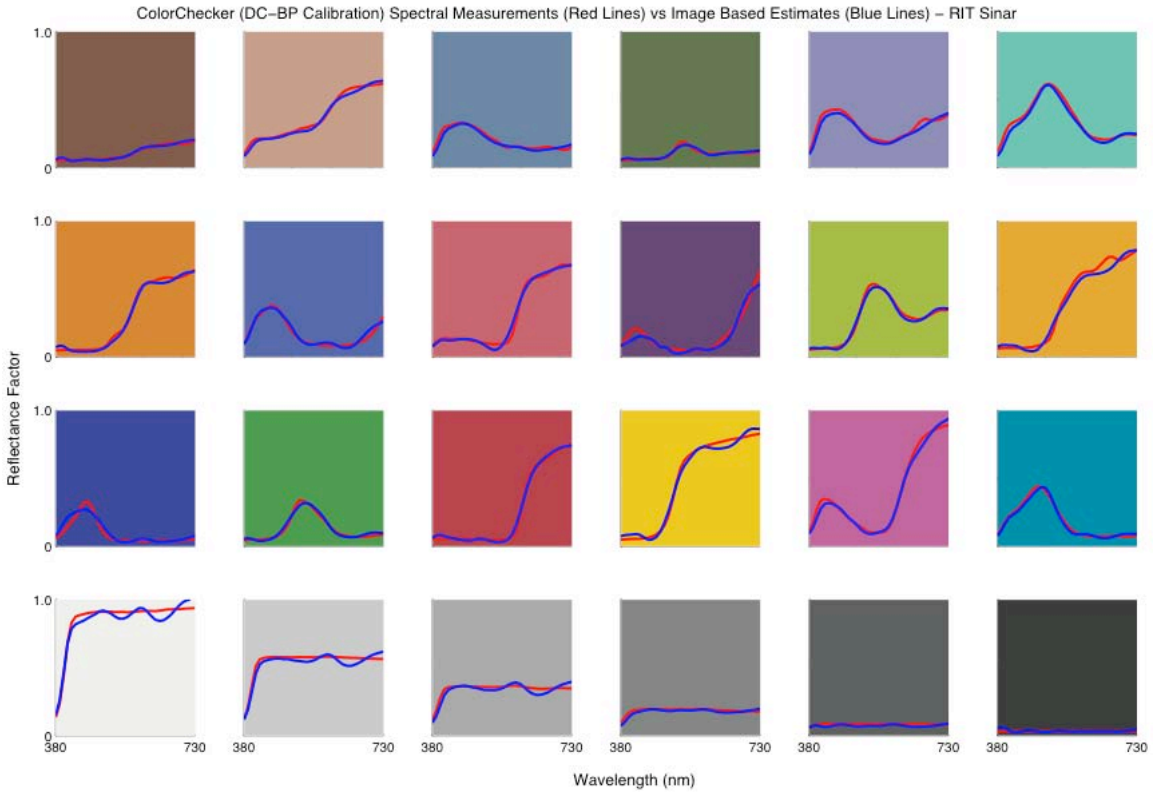


Figure 7. The average spectral root-mean-square performance of each imaging system for each listed target.



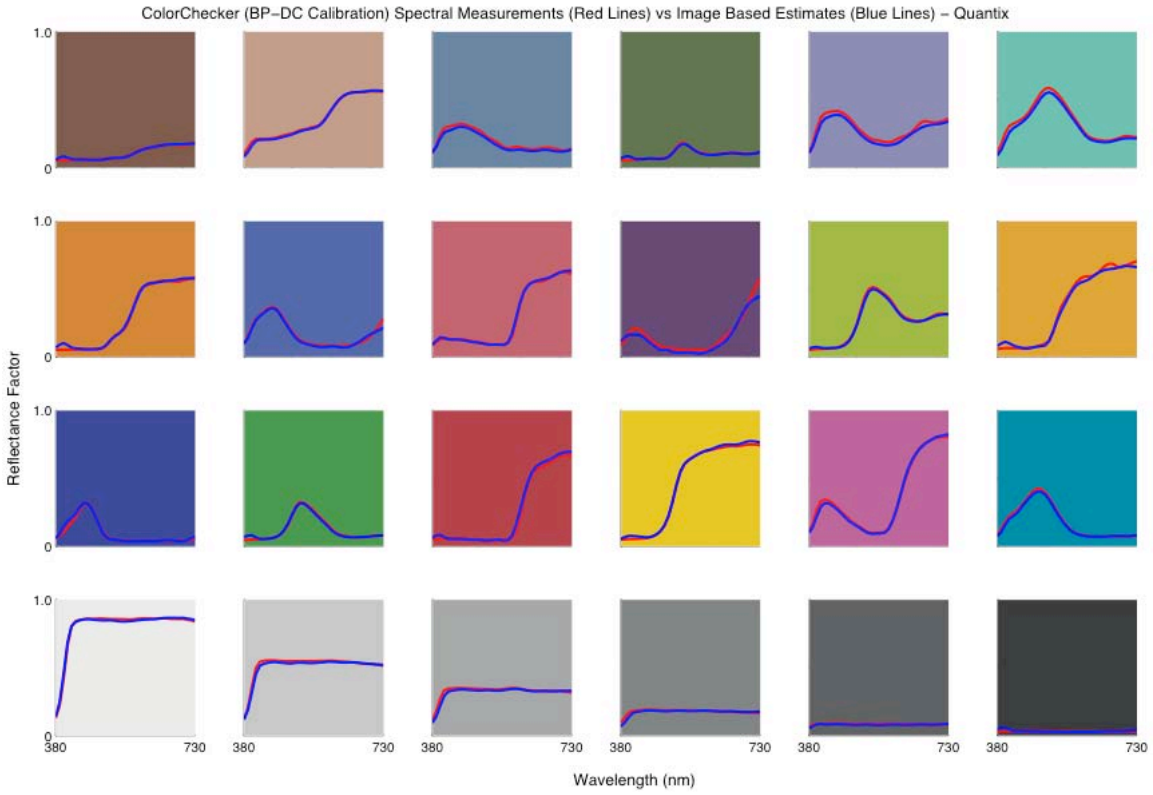


Figure 10. Spectral comparison between reference spectrophotometer (red) and imaging system (blue). Top: MCSL-Sinar; Bottom: Quantix-LCTF.

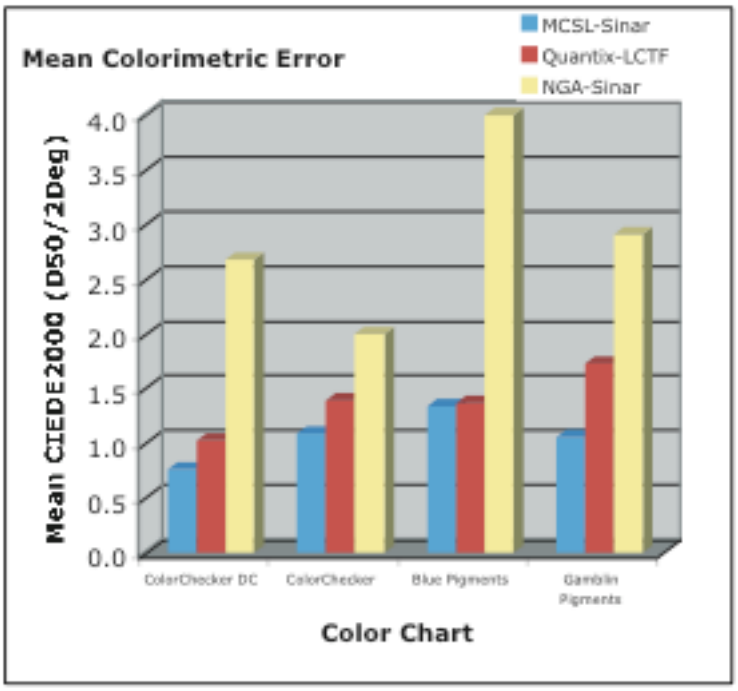


Figure 5. The average colorimetric performance of each imaging system for each listed target.

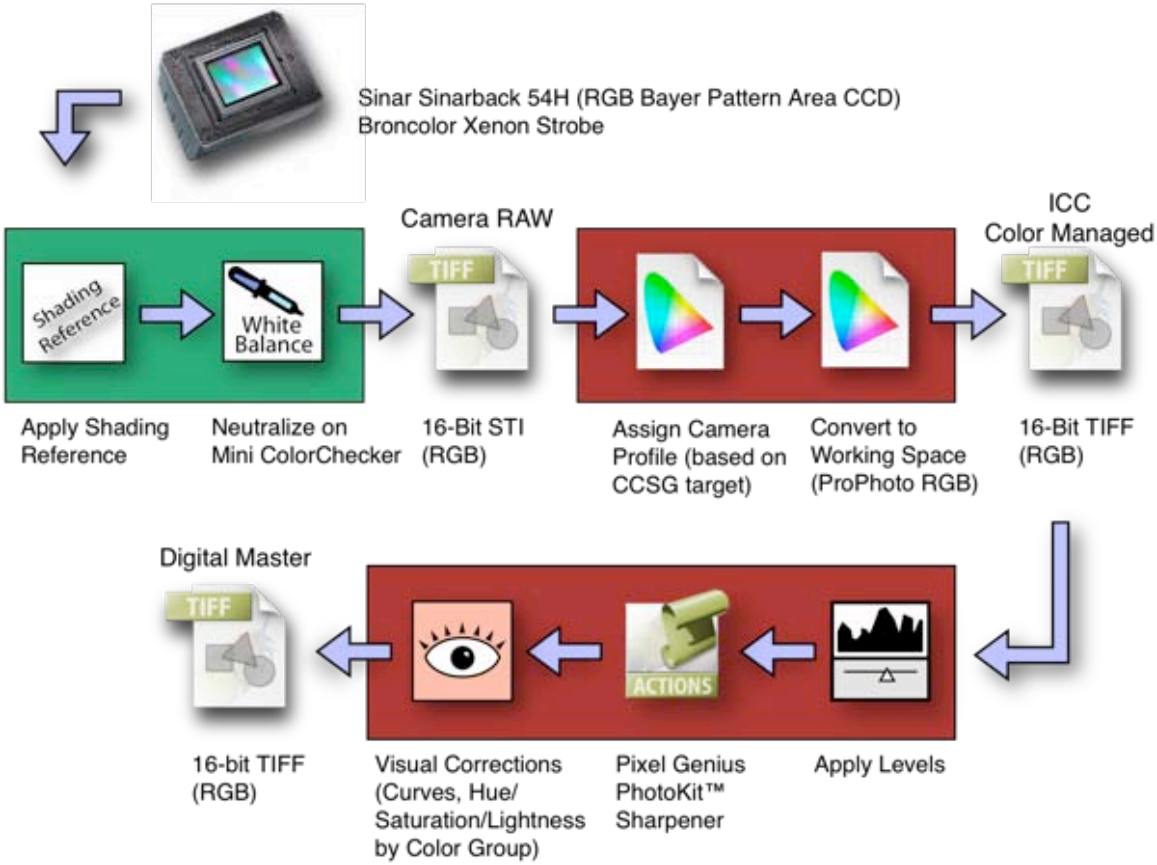


Figure 1. NGA's digital workflow. Areas in green are camera software processing. Areas in red are Adobe Photoshop software processing.

Adobe® Photoshop® CS2

The professional standard in desktop digital imaging

Product overview

Adobe Photoshop CS2 software, the professional image-editing standard and leader of the Photoshop digital imaging line, delivers more of what you crave. Groundbreaking creative tools help you achieve extraordinary results. Unprecedented adaptability lets you custom-fit Photoshop to the way you work. And with more efficient editing, processing, and file handling, there's no slowing you down.

Create with unmatched power

Timesaving file handling with Adobe Bridge (formerly the File Browser)

Multitasking

➤ Take advantage of compact floating mode in Adobe Bridge to process images while simultaneously working in Photoshop CS2 or other CS2 applications.

Viewing options

➤ Easily browse your Adobe Creative Suite and other graphics files in Adobe Bridge; present your images with features like Slideshow and Filmstrip mode; scale thumbnails to any size using a slider; and view and edit metadata.

Automated batch processing

➤ Automatically process batches of images in Adobe Bridge to rename, convert format, adjust exposure, create a Web gallery or Adobe PDF Presentation, and more.

Rating and labeling

➤ Quickly rate and label photos in Adobe Bridge so you can instantly bring up your best shots.

Sophisticated search

➤ Easily find any image using sophisticated search capabilities in Adobe Bridge that let you specify a variety of parameters. Save searches as Collections that you can recall anytime.

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Match Color command

• Achieve a consistent look between package shots, fashion photos, and more by instantly matching the color scheme of one image to another.

Color Replacement tool

• Easily change the color of any image area while retaining the original texture and shading.

32-bit High Dynamic Range (HDR) support

➤ Create and edit 32-bit images, and combine multiple exposures into a single, 32-bit image with expanded range—from the deepest shadows to the brightest highlights.

Histogram palette

• Monitor color changes to your image in the Histogram palette, which dynamically updates as you make adjustments.

Adobe

Shadow/Highlight correction

- Quickly improve the contrast of over- or underexposed areas of an image, including CMYK images, while preserving the overall balance of the photo.

Color management guidance

- Get precise, consistent color from display to output with helpful color management guidance.

Intelligent image editing

Revolutionary Vanishing Point

- Achieve amazing results in a fraction of the time with the groundbreaking Vanishing Point, which lets you clone, paint, and paste elements that automatically match the perspective of the surrounding image area.

Image Warp

- Easily create packaging mock-ups or other dimensional effects by wrapping an image around any shape or stretching, curling, and bending an image using Image Warp.

Spot Healing Brush

- Effortlessly retouch photos—including 16-bit images—in a single click with the advanced power of the new Photoshop CS2 Spot Healing Brush.

Healing Brush

- Perform expert retouching to remove dust, scratches, blemishes, wrinkles, and other flaws with minimal effort using the Healing Brush.

Essential photography tools

One-click red-eye correction

- Instantly neutralize red eyes with the one-click red-eye correction tool, which supports 16-bit images and lets you set pupil size and darkening level.

Optical lens correction

- Easily correct common lens distortions, such as barrel and pincushion, and fix chromatic aberrations and vignetting.

Smart Sharpen

- Easily counteract common image blurring with fine correction control based on the specific blur types: motion, lens, and Gaussian.

Advanced noise reduction

- Polish digital photos with advanced noise correction in high-ISO shooting plus JPEG artifact reduction.

Camera raw workflow enhancements

- Process an entire photo shoot in a fraction of the time by simultaneously adjusting color, curves, cropping, and more—and continue working in Photoshop! With support for a comprehensive range of digital cameras, Photoshop CS2 lets you automatically adjust settings, convert to Digital Negative (DNG) format, and apply nondestructive edits to batches of images.

Comprehensive 16-bit support

- Perform precise editing and retouching with support for 16-bit images in core features, including layers, brushes, text, shapes, and more.

Crop and Straighten command

- Scan multiple images at once and let Photoshop automatically straighten and save each image as an individual file.

Design freedom

Flexible layers

- Composite images, text, and effects on hundreds of layers that you can organize with up to five levels of nesting and save in different combinations as Layer Comps.

Painting and drawing tools

- Create or modify images with a wide assortment of professional, fully customizable paint settings, artistic brushes, and drawing tools.

Special effects filters

- Achieve amazing results with more than 95 special effects filters. Easily preview and apply more than one filter at a time from the Filter Gallery.

Advanced type control

- Add vector-based text that you can edit at any time, format, warp, place on a path, convert to outlines, and use for masks or other special effects.

Advanced Web capabilities

- Create sophisticated Web page elements with rollovers, transparency, image slicing, and more.

Web animations

- Quickly create dynamic GIF animations—using one or more images—directly within Photoshop CS2 by taking advantage of the new Animations palette and layer palette animation options.

Customize with unprecedented adaptability

Adaptable workspace

Custom menus and keyboard shortcuts

- Set up and save custom menus and keyboard shortcuts for quick access to the features you need.

Custom, task-based workspaces

- Reduce onscreen clutter by choosing from task-based workspaces, or create your own with just the tools you need.

Adobe Help Center

- Quickly get answers from the new, floating Adobe Help Center window with improved search features and convenient, task-based topics.

History Log

- Automatically track all editing steps within your Photoshop files. Export steps to a text file or save them as part of image metadata for easier documentation of your work, file audits, and more.

Flexible measurement systems

- Enter precise numeric values in inches, pixels, and other measurement systems. Even enter different measurements on-the-fly without changing global settings.

Automated image processing

Enhanced automation

- Use the new Image Processor command to process camera raw images, and use new built-in Actions to prepare images for film and video.

Event-based scripts

- Accomplish more in fewer steps with event-based scripts that automatically activate at specified points in your workflow.

Variables

- Instantly produce repetitive graphics with Variables, which automatically populate your design with data from spreadsheets or databases.

Actions and Droplets

- Automate common production tasks by recording editing steps in the Actions palette, and then processing batches of files with Droplets.

Film and video design

Non-square pixel support

- Create and work with different aspect ratios to accommodate non-square pixels without distortion.

Convenient video preview

➤ Design for broadcast more easily by previewing your Photoshop CS2 images on an NTSC or PAL monitor connected to your computer by IEEE 1394/FireWire/i.LINK.

32-bit HDR

➤ Create and edit 32-bit, High Dynamic Range (HDR) images for the widest range and richest detail.

Guide presets

- Easily design using video-specific presets that show action-safe and title-safe areas of the screen.

16-bit compositing

- Perform precise matte painting, 3D rendering, and other advanced film compositing with support for 16-bit images in core features.

Layers-to-files export

- Quickly integrate layered Photoshop artwork with a variety of video editing and compositing systems using the built-in Export Layers To Files command.

Work with unparalleled efficiency

Smooth workflow

Smart Objects

➤ Perform nondestructive scaling, rotating, and warping of raster and vector graphics with Smart Objects. Even preserve the editability of high-resolution vector data from Adobe Illustrator® software.

Multiple layer control

➤ Select and move, group, transform, and warp objects more intuitively by clicking and dragging directly on the canvas. Easily align objects with Smart Guides.

Smart Guides

➤ Design faster by automatically aligning objects to each other using Smart Guides.

WYSIWYG font menu

➤ Quickly select typefaces from the font menu, which now displays a sample of each font.

Adobe Creative Suite integration

➤ Work more smoothly across Adobe Creative Suite components with color-setting synchronization in Adobe Bridge, consistent viewing of onscreen color, and unified Adobe PDF file creation settings.

Multilingual spelling checker

- Avoid typos with the built-in spelling checker, which supports multiple languages and includes convenient search-and-replace functionality.

Instant video preview

➤ See your broadcast graphics as they'll appear to the audience, while you're still building them. With one click, you can preview your Photoshop CS2 images on a television monitor connected to your computer by IEEE 1394/FireWire/i.LINK.

Multi-image digital camera raw file processing

Simultaneous multiple-image editing

➤ Save time by processing batches of raw images at once with nondestructive editing, including color settings, cropping, straightening, adjusting curves, and more. Even process images while continuing to edit or retouch them.

Digital camera and Digital Negative (DNG) support

- Take advantage of support for a comprehensive range of digital cameras, and help ensure a lifetime of access to your digital camera raw files by converting them to the DNG format.

Automatic adjustments

- Instantly improve the appearance of images by automatically adjusting the exposure, contrast, and color of raw files.

Professional presentation

Enhanced Web photo galleries

- Quickly display your photos online and gather feedback from viewers using Web photo galleries that can now also include animations and sound.

Customizable Picture Packages

- Easily showcase your images by choosing from more than a dozen customizable Picture Package templates.

Adobe Photoshop Services

- Upload photos directly to Adobe Photoshop Services to share and order prints—even in large formats. Adobe Photoshop Services are provided in conjunction with Kodak EasyShare Gallery, the leader in online photo services and a Kodak company. (Note: Adobe Photoshop Services are not available in all countries.)

Adobe PDF Presentation

- Present your images in universally accessible Adobe PDF files, which include support for transitions and security options.

Improved printing workflow

- Easily configure your desktop inkjet printer for accurate color output.

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Adobe

Xserve G5

Designed from the ground up for high-density compute power, exceptional flexibility, and industry-leading ease of use.

Key Features

64-bit processing power. Xserve comes with single or dual PowerPC G5 processors, each with a dedicated frontside bus running at half the processor speed—maximizing performance with data transfer rates of up to 9.2GB/s.

Ultrafast ECC memory. A 128-bit memory controller speeds data in and out of main memory at up to 6.4GB/s. The Xserve G5 supports up to 8GB of DDR RAM with Error Correction Code (ECC) protection.

Server-optimized I/O. Two open 64-bit PCI-X slots provide throughput of up to 1GB/s for PCI devices. Dual Gigabit Ethernet and FireWire 800 interfaces offer high-performance connectivity.

Scalable storage. Three drive bays hold up to 1.2TB of internal storage[1] on independent Serial ATA channels for fast data access.[2] Optional cards connect to external storage and backup devices, including Apple's Xserve RAID.

UNIX-based operating system. An unlimited-client license for Mac OS X Server is included at no additional cost.[2] Built on open standards, Mac OS X Server integrates seamlessly into enterprise infrastructures.

Built-in management tools. Easy-to-use software enables you to monitor multiple Xserve systems and manage services over a secure, remote connection.

Comprehensive service and support. To ensure rapid issue resolution for your server and storage deployments, choose from a full range of AppleCare products designed to provide integrated expert support.

Specification Sheet
Xserve G5

Apple's Xserve G5 packs phenomenal power and industry-leading capabilities into an ultradense 1U rackmount server that fits easily into any network environment. It comes with Mac OS X Server, Apple's UNIX-based server operating system, providing a complete suite of standards-based network services with no per-client fees. Integrated remote management and monitoring tools make Xserve G5 a breeze to set up and manage—reducing the complexity of system administration and minimizing maintenance costs. Whether in small or large business, higher education or K–12 schools, creative departments, or science and technology research centers, the affordable Xserve G5 is the perfect server for today's new breed of open standards–based network solutions.

Xserve G5 Configurations

	Server configurations		**Cluster node**
Order number	**M9743LL/A**	**M9745LL/A**	**M9742LL/A**
Processor	2GHz PowerPC G5	Dual 2.3GHz PowerPC G5	Dual 2.3GHz PowerPC G5
Frontside bus	1GHz	1.15GHz per processor	1.15GHz per processor
ECC memory	1GB PC3200 DDR (400MHz)	1GB PC3200 DDR (400MHz)	512MB PC3200 DDR (400MHz)
Maximum memory	8GB	8GB	8GB
Hot-plug storage (Serial ATA)	Three drive bays supporting up to 1.2TB using 80GB, 250GB, and/or 400GB Apple Drive Modules; one 80GB drive preinstalled[1]		One drive bay with 80GB drive preinstalled[1]
Optical drive	Combo drive (DVD-ROM/CD-RW) or optional SuperDrive (DVD-R/CD-RW)		—
Networking	Two onboard Gigabit Ethernet interfaces (10/100/1000BASE-T)		
PCI expansion	Two open 64-bit PCI-X slots supporting one card at up to 133MHz or two cards at up to 100MHz		
Ports	Two FireWire 800, two USB 2.0, one DB-9 (back panel); one FireWire 400 (front panel)		
Mac OS X Server software	Unlimited-client edition	Unlimited-client edition	10-client edition
Also included	Mounting screws with M5 and 1/32-inch threads; caged nuts; cable management arm for four-post racks; agency-approved 12-foot power cable		
Service and support	90 days of telephone support and one-year limited warranty; optional extended service and support products		

Xserve G5 cluster node
With the compute performance of two superscalar 2.3GHz PowerPC G5 processors, the Xserve G5 cluster node configuration is ideal for High Performance Computing (HPC) in scientific and technical environments, as well as for workgroup clusters and render farms.[2] For more information about Apple solutions for computational clusters, see www.apple.com/xserve/cluster.

Xserve RAID
Connect Xserve to Apple's affordable Xserve RAID storage solution for enormous capacity—up to 5.6TB[1]—and advanced data protection in a high-availability 3U enclosure.

Technical Specifications

Processor
- Single 2GHz or dual 2.3GHz PowerPC G5 processors
  - PowerPC processor architecture with 64-bit data paths and registers
  - Native support for 32-bit application code
  - 512K on-chip L2 cache running at processor speed
  - Dual-pipeline Velocity Engine for 128-bit single-instruction, multiple-data (SIMD) processing
  - Two independent double-precision floating-point units and two integer units
  - Advanced three-stage branch prediction logic
- 64-bit, 1GHz or 1.15GHz frontside bus per processor, supporting up to 18.4GB/s data throughput
- Point-to-point system controller with support for ECC memory

Memory
- 128-bit data paths for up to 6.4GB/s memory throughput
- Data protection using Error Correction Code (ECC) logic
- Eight slots supporting up to 8GB of DDR SDRAM using the following DIMMs (in pairs):
  - 256MB DIMMs (PC3200, 400MHz ECC)
  - 512MB DIMMs (PC3200, 400MHz ECC)
  - 1GB DIMMs (PC3200, 400MHz ECC)

I/O connections
- Two open 12-inch, 64-bit PCI-X slots, running at up to 133MHz with one card installed or up to 100MHz with two cards installed; support for 32-bit or 64-bit 3.3V Universal PCI cards running at 33MHz or 66MHz[3]
- PCI and PCI-X cards available as build-to-order options for Xserve G5 include the following:
  - Apple Fibre Channel PCI-X Card
  - Hardware RAID PCI card
  - Apple PCI-X Gigabit Ethernet Card
  - Dual-channel Ultra320 SCSI PCI-X card
  - PCI VGA video card
- Two independent 10/100/1000BASE-T (Gigabit) RJ-45 Ethernet interfaces on main logic board
- Two FireWire 800 ports on back panel and one FireWire 400 port on front panel; 15W total power
- Two USB 2.0 ports (480Mb/s each)
- One DB-9 serial port (RS-232)

Storage
- Three internal drive bays on independent 150MB/s Serial ATA channels (server configurations; empty drive bays contain blank modules); or one internal drive bay on 150MB/s Serial ATA channel (cluster node configuration)
- Up to 1.2TB of internal storage[1] using hot-plug Apple Drive Modules (server configurations), available in the following capacities:
  - 80GB 7200-rpm SATA with 8MB disk cache
  - 250GB 7200-rpm SATA with 8MB disk cache
  - 400GB 7200-rpm SATA with 8MB disk cache
- Support for reading SMART data from Apple Drive Modules for prefailure notification
- Slot-loading Combo drive (DVD-ROM/CD-RW) or optional SuperDrive (DVD-R/CD-RW)[2]

Rack support
- Fits EIA-310-D–compliant, industry-standard 19-inch-wide racks, including:
  - Four-post racks: 24 inches, 26 inches, and from 29 to 36 inches deep
  - Two-post telco racks (center-mount brackets included)
- Cable management arm for four-post rack
- Front-to-back cooling for rack enclosure

Electrical requirements
- Line voltage: universal input (90V to 264V AC), power factor corrected
- Maximum input current: 4A (90V to 132V) or 2A (180V to 264V)
- Frequency: 47Hz to 63Hz, single phase
- Output power: 400W

Environmental requirements and approvals
- Operating temperature: 50° to 95° F (10° to 35° C)
- Storage temperature: –40° to 116° F (–40° to 47° C)
- Relative humidity: 5% to 95% noncondensing
- Maximum altitude: 10,000 feet
- FCC Class A approved

Size and weight
- Height: 1.73 inches (4.4 cm)
- Width: 17.6 inches (44.7 cm) for mounting in standard 19-inch rack
- Depth: 28 inches (71.1 cm)
- Weight: 33.3 pounds (15.11 kg); 36.6 pounds (16.62 kg) with three Apple Drive Modules[4]

For More Information

For more information about Xserve G5, Xserve RAID, Xsan, and other Apple server solutions, visit www.apple.com/server.

For more information on AppleCare service and support products, visit www.apple.com/support/products.

[1]For hard drive capacity measurements, 1GB = 1 billion bytes and 1TB = 1 trillion bytes; actual formatted capacity less [2]Server configurations only; the cluster node configuration has one drive bay and no optical drive and includes a 10-client license for Mac OS X Server. [3]Check with manufacturer for compatibility. [4]Weight varies by configuration and manufacturing process.

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January 2005 L307491A

Xserve RAID

This high-performance, high-availability storage system delivers data protection and enormous capacity—up to 5.6 terabytes—at a groundbreaking price.

Key Features

Massive storage capacity. Fourteen drive bays hold up to 5.6TB of storage.[1] Independent Ultra ATA drive channels maximize bandwidth and availability.

High-speed throughput. The dual independent 2Gb Fibre Channel host interface transfers terabytes of data at up to 400MB/s.[2]

Superior data protection. A high-availability architecture and dual independent RAID controllers support RAID levels 0, 1, 3, 5, and 0+1.

Maximum uptime. Xserve RAID keeps running with redundant, hot-swappable power supplies and cooling modules.

Remote management. The Java-based RAID Admin application makes it easy to set up, manage, and monitor Xserve RAID systems from virtually anywhere on the Internet.

Cross-platform compatibility. Xserve RAID fits into Linux, Windows, NetWare, and mixed-platform environments and is certified for compatibility with leading storage infrastructure solutions.[3]

Comprehensive service and support. To ensure rapid issue resolution for your server and storage deployments, choose from a full range of AppleCare products designed to provide integrated expert support.

With massive capacity and high-availability features previously available only in much more expensive storage systems, Xserve RAID offers unmatched capabilities for an unprecedented price. Tiered storage environments can take advantage of its extreme versatility. Redundant components provide the continuous availability required for business-critical applications. The dual 2Gb Fibre Channel interface and 14 independent drive channels deliver a sustained throughput of up to 380MB/s—fast enough for the most demanding media production environments.[4] And with pricing at just over $2 per gigabyte, Xserve RAID is affordable enough for near-line storage deployments.

A platform-independent design and Java-based administrative tools make it easy to fit Xserve RAID into heterogeneous environments. Xserve RAID is qualified for use with Linux, Windows, and NetWare systems, and Apple has worked with leading storage infrastructure vendors to certify it for integration with existing Fibre Channel hardware and data management solutions.[3] Integrated remote monitoring and notification features and hot-swappable components ensure that your data is online and available, all the time. And with intuitive tools for quick configuration of protected storage volumes, this revolutionary RAID solution delivers ease of use that could come only from Apple.

Xserve RAID Configurations

Order number	M9721LL/A	M9722LL/A	M9723LL/A
Price (U.S. MSRP)	$5999	$8499	$12,999
Total available storage—RAID 0	1TB[1]	2.8TB[1]	5.6TB[1]
Usable storage—RAID 1	500GB[1]	1.2TB[1]	2.4TB[1]
Usable storage—RAID 3 and 5	750GB[1]	2.4TB[1]	4.8TB[1]
Apple Drive Modules	Four 250GB drives[1]	Seven 400GB drives[1]	Fourteen 400GB drives[1]
On-drive cache	8MB per drive	8MB per drive	8MB per drive
Controller cache	512MB per controller	512MB per controller	512MB per controller
Expansion	Fourteen drive bays with independent Ultra ATA channels for up to 5.6TB of storage[1]		
Also included	Mounting screws with M5, M6, and 10/32-inch threads; caged nuts; two agency-approved 12-foot power cables		
Software	RAID Admin Tools CD		
Service and support	90 days of telephone support and one-year limited warranty; optional extended service and support products		

Note: 250GB drives are also available in 7- and 14-drive configurations.

Third-party certifications
Leading storage infrastructure vendors have certified Xserve RAID for integration with existing Fibre Channel hardware and data management solutions, including:

- QLogic
- Brocade
- Emulex
- LSI Logic
- VERITAS
- ATTO Technology
- Candera
- Cisco

In addition to Mac OS X and Mac OS X Server, Xserve RAID has been qualified for use on these operating systems:

- Windows Server 2003
- Windows 2000 Server
- Windows 2000 Professional
- Red Hat Enterprise Linux v2.1 and v3
- Novell NetWare v5.x and v6.x
- SUSE Enterprise Server 9
- Yellow Dog Linux v3

Xserve G5. Xserve RAID works seamlessly with Xserve G5, Apple's high-density 1U rack-optimized server. Equipped with single or dual PowerPC G5 processors, Xserve packs phenomenal power and a rich feature set into an affordable, easy-to-deploy system.

Xsan. Xserve RAID and Xsan create an enterprise-class storage solution. Xsan, Apple's 64-bit SAN file system for Mac OS X, allows computers to concurrently access shared storage over a high-speed Fibre Channel connection. Xsan streamlines workgroup collaboration and bandwidth-intensive workflows and increases the flexibility and scalability of server deployments.

For More Information

For more information about Xserve RAID, Xserve G5, Xsan, and other Apple server solutions, visit www.apple.com/server.

For information on AppleCare service and support products, visit www.apple.com/support/products.

Technical Specifications

Storage

- Fourteen drive bays on independent 100MB/s channels supporting up to 5.6TB of total storage[1] using Apple Drive Modules, available in the following capacities:
  – 250GB 7200-rpm Ultra ATA with 8MB disk cache
  – 400GB 7200-rpm Ultra ATA with 8MB disk cache and rotational vibration safeguard
- Empty drive bays contain blank modules
- Support for reading SMART data from Apple Drive Modules for prefailure notification

RAID controllers and cache memory

- Dual independent controllers, each with an environment management coprocessor for out-of-band remote management and monitoring
- 512MB of cache memory per controller (1GB total)
- Cache Backup Battery Modules (sold separately) for over 72 hours of memory protection

RAID operation

- Support for RAID levels 0, 1, 3, 5, 0+1, 10, 30, and 50 (10, 30, and 50 using host-based software RAID)
- Support for multiple RAID sets, multiple hosts, and LUN masking and mapping
- Background RAID set creation; automatic variable background rebuilding[5]; online expansion; LUN slicing; global drive hot sparing (per RAID controller)

Fibre Channel storage-to-host connection

- Dual 2Gb Fibre Channel ports (SFP); 200MB/s throughput per channel with guaranteed bandwidth (400MB/s full duplex)[2]
- Host connectivity using 2Gb Apple Fibre Channel PCI-X Card (sold separately) or compatible third-party PCI and PCI-X cards
- Support for point-to-point, loop, and switched fabric topologies
- Dual 10/100BASE-T Ethernet interfaces for remote management

Apple Fibre Channel PCI-X Card (sold separately)

- 64-bit, 133MHz card with two SFP 2Gb Fibre Channel ports; compatible with 32-bit, 66MHz PCI slots and 64-bit, 100MHz or 133MHz PCI-X slots
- Two 2.9-meter Fibre Channel copper cables with SFP transceivers; compatible with short- and long-haul SFP transceivers and fiber-optic cables

Cooling

- Redundant, hot-swappable cooling modules with self-regulating speeds and front-to-back cooling
- Environmental monitoring system for automatically maintaining optimal ambient temperature

Electrical

- Redundant, load-sharing hot-swappable power supplies (450W); universal input (100V to 240V AC), power factor corrected
- Maximum input current: 7.6A (100V to 127V) or 3.6A (200V to 240V)
- Power usage: 300W typical continuous power, 400W maximum continuous power
- Dual DB-9 serial ports for UPS systems
- Frequency: 50Hz to 60Hz, single phase

Environmental requirements and approvals

- Operating temperature: 50° to 95° F (10° to 35° C)
- Storage temperature: –40° to 116° F (–40° to 47° C)
- Relative humidity: 5% to 95% noncondensing
- Maximum thermal output: 1365 BTUs per hour
- Maximum altitude: 10,000 feet
- FCC Class A approved

Size and weight

- Height: 3U rack-optimized, 5.25 inches (13.3 cm)
- Width: 17 inches (43.2 cm)
- Depth: 18.4 inches (46.7 cm)
- Fits EIA-310-D–compliant, industry-standard 19-inch-wide four-post racks from 24 to 36 inches deep; deeper racks require third-party extender
- 60 to 110 pounds (27 to 45 kg), depending on configuration

[1]For hard drive capacity measurements, 1GB = 1 billion bytes and 1TB = 1 trillion bytes; actual formatted capacity less. Maximum capacity of 5.6TB achieved through use of fourteen 400GB Apple Drive Modules. Usable capacity depends on drive configuration and RAID level. [2]Actual rates will vary depending on drive configuration and RAID level. [3]See www.apple.com/xserve/raid for more information on third-party certifications and qualifications. [4]Testing conducted by Apple in October 2004 using preproduction Xserve RAID systems. Iometer testing of raw disk throughput on Xserve RAID in both Mac OS X v10.3.6 "Panther" and Windows XP environments has shown that Xserve RAID is capable of delivering up to 192MB/s on the standard shipping 4 x 250GB disk configuration utilizing a single controller and an average of over 380MB/s on standard shipping 7 x 400GB and 14 x 400GB disk configurations utilizing both RAID controllers. Mac OS X v10.3.6 "Panther" Xserve RAID testing conducted using directly attached dual processor 2GHz Xserve G5 systems. Windows XP Xserve RAID testing conducted using directly attached dual processor 3.2GHz Xeon-based Dell Precision 650 systems. [5]Host operating system limitations apply.

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Data sheet

Product designation

Power pack Grafit A4 Article no. 31.176.XX

Product description

Microprocessor controlled power pack (3200 J) with 3 lamp base connections, stabilized colour temperature on 2 main connections, variable output distribution (asymmetrical/symmetrical), 6.7 f-stops for main connections, 4 f-stops for reserve connection, in 1/10 or 1/3 f-stop intervals, display simultaneously in joules and f-stops, joules switchable to percentage, fully illuminated control panel and LCD-display, flash duration selectable on main connections, short-time exposure selectable, CTC (Colour Temperature Control) for uniform or deliberately variable colour temperature with broncolor FCC (Flash Colour Chronoscope), proportional modelling light over entire output range.
Additional functions: Flash sequences, triggering delay, selectable flash duration, slow charging, ping-pong release, stroboscopic effects with one or more power packs, choice of two infrared channels, etc., user-friendly menu functions, menu text available in multiple languages (German, English, French, Spanish, Japanese, Swedish, Indonesian).

Scope of delivery

Power pack with mains cable, operating instructions, dust cover.

Technical data

Flash energy	3200 J
F-stop at 2 m (6 1/2 ft.), 100 ISO, reflector P70	90 2/10
Flash duration t 0.1 (t 0.5)	1/80 - 1/6000 s (1/240 - 1/10000 s) Flash duration and energy automatically regulated for optimum colour temperature. Flash duration can be preselected.
Charging time (for 100% of selected energy)	Version 1 (230 V): 0.04 - 2.6s Version 2 (120 V): 0.04 - 3.2s Version 3 (100 V): 0.04 - 4.4s Can be switched to slow charging mode for low-amperage power outlets
Ready display	Visual and audible (can be switched off); signals when 100 % of selected energy is reached
Lamp base connections	2 main connections with flash cut-off and 1 reserve connection
Power output distribution	Symmetrical and variable asymmetrical
Controls	Illuminated silicone keyboard, resistant to dust and scratches. Wireless remote control with infrared Servor e.
Control range	6 7/10 f-stops for main connections, 4 f-stops for reserve connection, in 1/10 or 1/3 f-stop intervals

Data sheet

	Display simultaneously in joules and f-stops, joules switchable to percentage
Colour temperature	CTC (Colour Temperature Control) for uniform or deliberately variable colour temperature with broncolor FCC (Flash Colour Chronoscope)
Modelling light	Halogen, max. 3 x 650 W at 200-240 V Halogen, max. 3 x 300 W at 100-120 V Proportional to flash energy and «full» and «low» settings. Proportionality adjustable to other broncolor power packs, compact units and their various output ranges
Additional functions	Flash sequences, triggering delay, selectable flash duration, slow charging, ping-pong release, stroboscopic effects with one or more power packs, a choice of two infrared channels, etc. Easy to use menu operated functions, menu text available in multiple languages (German, English, French, etc.)
Flash release	Manual release button, sync cable, selectable photocell or wireless via selectable IR-receiver
No. of sync sockets	2
Stabilized flash voltage	+/- 0.5%
Standards	EC standard 73/23, UL 122
Power requirements	Version 1: 220-240 V / 50 Hz, switchable to 120 V / 60 Hz, current consumption 10 A, longer series with shorter charging times 16 A. Version 2: 110-120 V / 60 Hz, switchable to 230 V / 50 Hz, current consumption 15 A. Version 3: 100 V / 50 Hz, switchable to 230 V / 50 Hz, current consumption 15 A.
Dimensions	288 x 180 x 407.5 mm
Weight	11 kg

Compatibility

Lamp bases	Pulso 2, F2, 4, F4, 8*, Pulso Twin, Pulso G, Primo, Picolite, Mobilite Ringflash, Pulso-Spot 4 Universal lamp base, with RT plug *Pulso lamp base 8 may only be used on the auxiliary outlet (lamp plug no. 3)
Remote control	Servor d, Servor e, Servor 3, Servor 2 (without additional functions)
Remote release	IRX 2, IRX, IRS-E, IRQ, FCM2, FCC, IRS IRI, FM

Special features

Automatic colour temperature control, called CTC.
The auxiliary functions may be used for example for:
- alternating release to reduce flash sequence times using two power packs (ping-pong mode)
- fast strobo sequences (can be used as quasi-continuous light to assess precisely shadow edges, etc.)

Application

Grafit A power packs allow interesting shots which go beyond the characteristics and options of conventional units by combining flash sequences, delays, etc.. This opens a new range of creative activities which can be applied only with the Grafit A power packs.
The very short flash duration and charging time with reduced flash energy plus the extremely low heat build-up in spite of a very short flash duration make the Grafit A suitable for fashion photography where long flash sequences are applied.

Product designation

Pulso G lamp base Article no. 32.121.XX

Product description

Lamp base with sturdy Noryl housing and grip. Bayonet mount with automatic lock for interchangeable reflectors and various area lamps. Plug-in flash tube with ceramic socket and spring for secure hold. The lamp base can be fitted either with 1600 J or 3200 J flash tubes (details, see chapter “special features / restrictions”). Switch and fuse for modelling light. The protecting glass is available in 5500 K or 5900 K as well as “clear” or “mat”. Safer protecting glass holder thanks to mechanical lock. Integrated tilting head with locking lever. Umbrella holder. Light angle may be adjusted by a rotary knob fitted at side. Focusing possible within 26 mm range, resulting in illumination angle adjustment from 60° - 90° (P70). Equipped with thermal protection. Cooling fan for long flash sequences. Suitable for mains voltages from 100 to 240 V thanks to the stabilized fan supply (Attention: The lamp base must be fitted with a corresponding modelling lamp).

Also usable with battery-powered Mobil power pack (without modelling light when using on battery).

Scope of delivery

Lamp head, protection cap, lamp base cable 5 m, bag with replacement fuse, safety bolt for suspension mounting

Flash tube, modelling lamp and protecting glass to be ordered separately.

Technical data

Flash energy	max. 3200 J
F-stop at 2 m distance 100 ISO, reflector P70	64 2/10 resp. 90 2/10 (with Grafit)
Modelling light (fuse value)	650 W halogen (3.15 AF) 230 - 240 V 300 W halogen (3.15 AF) 100 - 120 V
Length of cable	5 m
Cooling	stabilized fan
Dimensions	over all 310 x 130 x 200 mm diameter 80 mm
Weight incl. cable	3.145 kg
Stand support	for broncolor bolt 12 mm, 3/8" thread and Manfrotto bolt 16 mm

Compatibility

Power packs

Grafit 2, 4, A2, A4, A8, A2 RFS, A4 RFS, A8 RFS, A2 plus, A4 plus
Topas A2, A4, A8
Nano 2, Nano A4
Mobil
Primo, Primo A, Primo A fashion, Primo 4
Pulso 2, 4, A2, A4
Opus 2, 4, A2, A4, A8
304, 404, 404 Servor

Accessories

Flash tube (5900 K)	3200 J	Art. no. 34.324.00
Flash tube UVE (5500 K)	1600 J	Art. no. 34.322.55
Flash tube (5900 K)	1600 J	Art. no. 34.322.59
Protecting glass (5500 K)		Art. no. 34.336.55
Protecting glass (5900 K)		Art. no. 34.336.59
Protecting glass (5500 K)	mat	Art. no. 34.337.55
Protecting glass (5900 K)	mat	Art. no. 34.337.59
Lamp extension cable 5 m		Art. no. 34.151.00
Lamp extension cable 10 m		Art. no. 34.152.00
Halogen modelling lamp 300 W 100-120 V with fuse		Art. no. 34.225.XX
Halogen modelling lamp 650 W 220-240 V with fuse		Art. no. 34.226.10
Pulso-Flooter S		Art. no. 32.430.00
Reflector Mini-Hazylight		Art. no. 33.133.00
Reflector Mini-Cumulite		Art. no. 33.141.00
Reflector P-Travel		Art. no. 33.103.00
Narrow angle reflector P45		Art. no. 33.104.00
Narrow angle reflector P50		Art. no. 33.105.00
Standard reflector P65		Art. no. 33.106.00
Standard reflector P70		Art. no. 33.107.00
Softlight reflector P		Art. no. 33.110.00
Wide angle reflector P120		Art. no. 33.112.00
Conical snoot		Art. no. 33.120.00
Reflector Satellite Evolution		Art. no. 33.150.00
Reflector Satellite Staro		Art. no. 33.151.00
Reflector Mini-Satellite		Art. no. 33.152.00
Sunlite-Set (5500 K)		Art. no. 33.160.00
Balloon		Art. no. 33.161.00

Accessories (continuation)

Umbrella ∅ 102cm white/silver/transparent	Art. no. 33.452.00–33.454.00
Umbrella ∅ 82cm white/silver/transparent	Art. no. 33.459.00–33.461.00
Umbrella reflector	Art. no. 33.496.00
Hazylight-Soft	Art. no. 33.513.00
Megaflex 2 x 1,2 m	Art. no. 33.520.00
Megaflex 3 x 1,2 m	Art. no. 33.521.00
Reflector Cumulite 2	Art. no. 33.534.00
Megalite system (different sizes)	Art. no. 33.540.00–33.541.06
Fresnel spot attachment	Art. no. 33.630.00
Projection attachment	Art. no. 33.640.00
Folding reflectors Pulsoflex EM	different sizes
Folding reflectors Pulsoflex C	different sizes
with adapter ring for Pulsoflex C/EM	Art. no. 33.400.00
with adapter ring fpr Pulsoflex C/EM and HMI F575 lamp base	Art. no. 43.100.00
Para / Para FF	different sizes

Special features / restrictions

Flash tubes for the Pulso G lamp base are available with a maximum capacity of 1600 J respectively 3200 J (see chapter “accessories”). With each flash tube, two stickers labelled “max. 1600 J” respectively “max. 3200 J” are enclosed, which must be stuck on the blue square onto the lamp plug as well as at the side of the tilting head of the lamp base. The Pulso G lamp base must not be charged above the indicated value.

For thermal reasons the UV filter coating of the flash tube 3200 J has been applied directly onto the protecting glass. The flash tube 1600 J however has the UV filter coating directly on the flash tube, for price reasons. The clear protecting glass does not have any optical effect. If a uniform fitting of all lamp base types is intended, the lamp base Pulso G may also be fitted with a clear flash tube 1600 J and coated protecting glass.

Due to the improved protecting glass holder, new protecting glasses are now also available. These have a marking line and three grooves at the rim. When inserting the protecting glass into the locking device of the Pulso G lamp base, the marking line must be at the top. After engaging the protecting glass, it must be slightly turned, to prevent accidental loosening. The previous protecting glasses are **not** compatible to the Pulso G lamp.

Warning: For safety reasons the lamp must not be operated without protecting glass.

The Pulso G lamp base can be operated worldwide with all mains voltages on condition that it is fitted with the corresponding halogen lamp for the local mains voltage.

Arguments

- Lamp base is convenient to handle and operate (quick replacement of reflectors)
- Resistance against breakage
- Excellent quality of cable reduces loss of energy
- Non-kinking cable in lamp base section and plug due to a special strain relief bush
- Long service life of halogen lamp and flash tube as a result of cooling; even for long flash sequences
- Plug-in flash tube with mechanical safety device
- Plug-in protection glass simplifies the adaptation of the colour temperature
- Protection glass with mechanical safety device
- Various flash tubes and protecting glasses available
- Operation possible on every power supply system worldwide
- Compatibe to the whole Pulso accessory assortment
- Built-in tilting head with locking head (locking lever M8 with threaded steel socket; optimal braking effect
- Stand support for broncolor bolts 12 mm, 3/8” thread and Manfrotto bolts 16 mm
- Umbrella holder
- Bayonet mount with automatic lock for interchangeable reflectors and various area lamps

EPSON Stylus Pro 7600 & 9600 Print Engine Specifications

Printing Method
7-color (CcMmYKk) EPSON UltraChrome Ink or
6-color (CcMmYKK) EPSON Photographic Dye Ink

Variable Droplet Micro Piezo DX3 drop-on-demand ink jet technology

Nozzle Configuration
Color and Monochrome heads: 96 nozzles x 7

Black Ink Mode Configurations
UltraChrome Ink	Photo-K + Light-K (standard), Matte-K + Light-K or Dual Matte-K
Photographic Dye Ink	Dual Photo-K only

Droplet Technology
Smallest droplet size: 4 picoliter
Variable Droplet Technology can produce up to 3 different sizes per print line

Resolution
2880 x 1440 dpi; 1440 x 720 dpi; 720 x 720 dpi; 720 x 360 dpi; 360 x 360 dpi; 360 x 180 dpi

Print Engine Speed
Depending upon the print mode being used, print engine speeds will vary from 8 ft^2/hr to a maximum of 192 ft^2/hr

Produces everyday "production quality" prints at ~87 ft^2/hr

Produces better than photo lab quality prints at ~16 ft^2/hr

Acoustic Noise Level
Approximately 50 dB(A) according to ISO 7779

Printer Language
EPSON ESC/P Raster Photographic Drivers standard

External server based Adobe PostScript 3 with optional software RIP. Also supported by most leading third-party RIPs and workflows

Operating Systems Supported
Macintosh	OS 8.5.1 through 9.x (OS X supported via RIP)
Windows	95, 98, Me, NT 4.x, 2000, and XP

Printer Interfaces
Includes one USB (1.1 and 2.0 compatible), one ECP Parallel and one Epson Expanson Slot for installing the optional internal IEEE 1394 FireWire or 10/100 BaseT Ethernet cards

Dimensions
SP7600	43.3" (W) x 22" (H) x 22.5" (D) 49.2" (H) with optional printer stand Printer weight: 96 lb
SP9600	63.9" (W) x 46.4" (H) x 28.2" (D) Printer weight: 185 lb with stand

BorderFree Printing
Left and right borderless "bleed" printing for the following media widths
SP7600 8", 10", 12", 14", 16", 20", 24"
SP9600 8", 10", 12", 14", 16", 20", 24", 36", 44"

Top and bottom edges can be automatically cut to any length three different ways during printing on roll media

YOU'VE GOT TO SEE IT IN EPSON COLOR™

Printable Area
Maximum paper width	**SP7600** – 24" **SP9600** – 44"
Left and right print margins	0 or 3mm each (0.24" total)
Maximum printable width	**SP7600** – 24.16" **SP9600** – 44.16"
Maximum printable length	Up to 100' (limited by roll length) (limited by software application)

Media Handling
SP7600	Media input	Single roll up to 24" width
	Cut sheet size	Up to 24" wide media (auto-loading)
SP9600	Media input	Single roll up to 44" width
	Cut sheet size	Up to 44" wide media (auto-loading)
Media core compatibility		Handles both 2" and 3" cored media
Max. roll media diameter		4" (2" core) or 6" (3" core)
Weight		12 lb bond up to 1.5 mm cardboard
Built-in media cutter		Automatic or manual cutting
Optional manual media cutter		Used for cutting very thick media

EPSON Intelligent Ink Cartridge
Ink cartridge size	110ml or 220ml[C] each color x 7 colors total
Ink cartridge shelf life	2 years from printed production date or 6 months after open for UltraChrome Ink and 2 years after open for Photographic Dye

On cartridge I.C. chip automatically tracks several ink usage data points for use in very accurate production cost estimations and reporting

Lightfastness Ratings[B]
EPSON UltraChrome Ink	Color:	Up to 100 years
	B&W:	Over 100 years
EPSON Photographic Dye Ink	Color:	Up to 26 years (EPSON ColorLife Media)
	B&W:	Not rated

Environmental Characteristics
Temperature operating	50° to 95° F (10° to 35° C)
Storage	-4° to 104° F (-20° to 40° C)
Humidity operating	20 to 80% relative humidity
Storage	5 to 85% relative humidity (no condensation)

Safety Approval
Safety standards	UL1950, CSA 22.2 950 FDA
EMI	FCC Part 15 subpart B class B, CSA C108.8 class B

Engine Reliability
Total print volume	20,000 B0 pages at 360 x 360 dpi
Print head life	28 billion shots per nozzle
Cutter life	~2,000 times (coated media)
Maintenance parts	Pump unit, flushing box, head cleaner, cap assembly

Electrical Requirements
Voltage	120 V (100 to 240 V)
Frequency	50 to 60 Hz
Current	1.0A / 100-120V
Power consumption	Approx. 55W (operating) <15W (standby) < .7W (power off mode) Energy Star compliant

Product/Accessories	Part Numbers SP7600	SP9600
EPSON Stylus Pro Print Engine w/ UltraChrome Ink	C472001UCM	C473001UCM
EPSON Stylus Pro Print Engine w/ Photographic Dye Ink	C472001DYE	C473001DYE
EPSON Stylus Pro Printer Stand	C12C844061	Included
EFI Fiery Spark Professional 2.0 Software RIP	C842832	C842832
Internal 10/100 BaseT Ethernet Type-B Card	C12C823912	C12C823912
Internal IEEE 1394 FireWire Type-B Card	C823722	C823722
Additional One-year EPSON Preferred Plus Service	EPP7696B1	EPP7696B1
Additional Two-year EPSON Preferred Plus Service	EPP7696B2	EPP7696B2
Automatic Take-up Reel System	Not Available	C12C815251
Replacement 44" Take-up Reel Core	Not Available	C815121
Paper Roller Spindle (Normal Tension) – 2" or 3"	C12C811161	C12C811151
Paper Roller Spindle (High Tension) – 2" or 3"	C12C811155	C12C811152
Replacement Printer Cutter Blade	C12C815241	C12C815241
Manual Media Cutting System	C12C815231	C815182
Replacement Manual Cutting Blade	C815192	C815192
Replacement Ink Maintenance Tank	C12C890071	C12C890071

EPSON Ink Technology SP7600 & SP9600 (110ml)	Photo Dye Ink	UltraChrome Ink
Photo Black ink cartridge	T545100	T543100
Cyan ink cartridge	T545200	T543200
Magenta ink cartridge	T545300	T543300
Yellow ink cartridge	T545400	T543400
Light Cyan ink cartridge	T545500	T543500
Light Magenta ink cartridge	T545600	T543600
Light Black ink cartridge	Not Available	T543700
Matte Black ink cartridge	Not Available	T543800

EPSON Ink Technology SP9600 (220ml)[C]	Photo Dye Ink	UltraChrome Ink
Photo Black ink cartridge	Not Available	T544100
Cyan ink cartridge	Not Available	T544200
Magenta ink cartridge	Not Available	T544300
Yellow ink cartridge	Not Available	T544400
Light Cyan ink cartridge	Not Available	T544500
Light Magenta ink cartridge	Not Available	T544600
Light Black ink cartridge	Not Available	T544700
Matte Black ink cartridge	Not Available	T544800

A The user selects the desired ink version at time of purchase.

B Ink lightfastness rating based on accelerated testing of prints on specialty media, displayed indoors, under glass. Actual print stability will vary according to media, printed image, display conditions, light intensity, humidity, and atmospheric conditions. Epson does not guarantee longevity of prints. For maximum print life, display all prints under glass or lamination or properly store them. Visit www.wilhelm-research.com for the latest information.

C 220ml ink cartridges available for the EPSON Stylus Pro 9600 only. 110ml ink cartridges come standard on the EPSON Stylus Pro 7600 and 9600.

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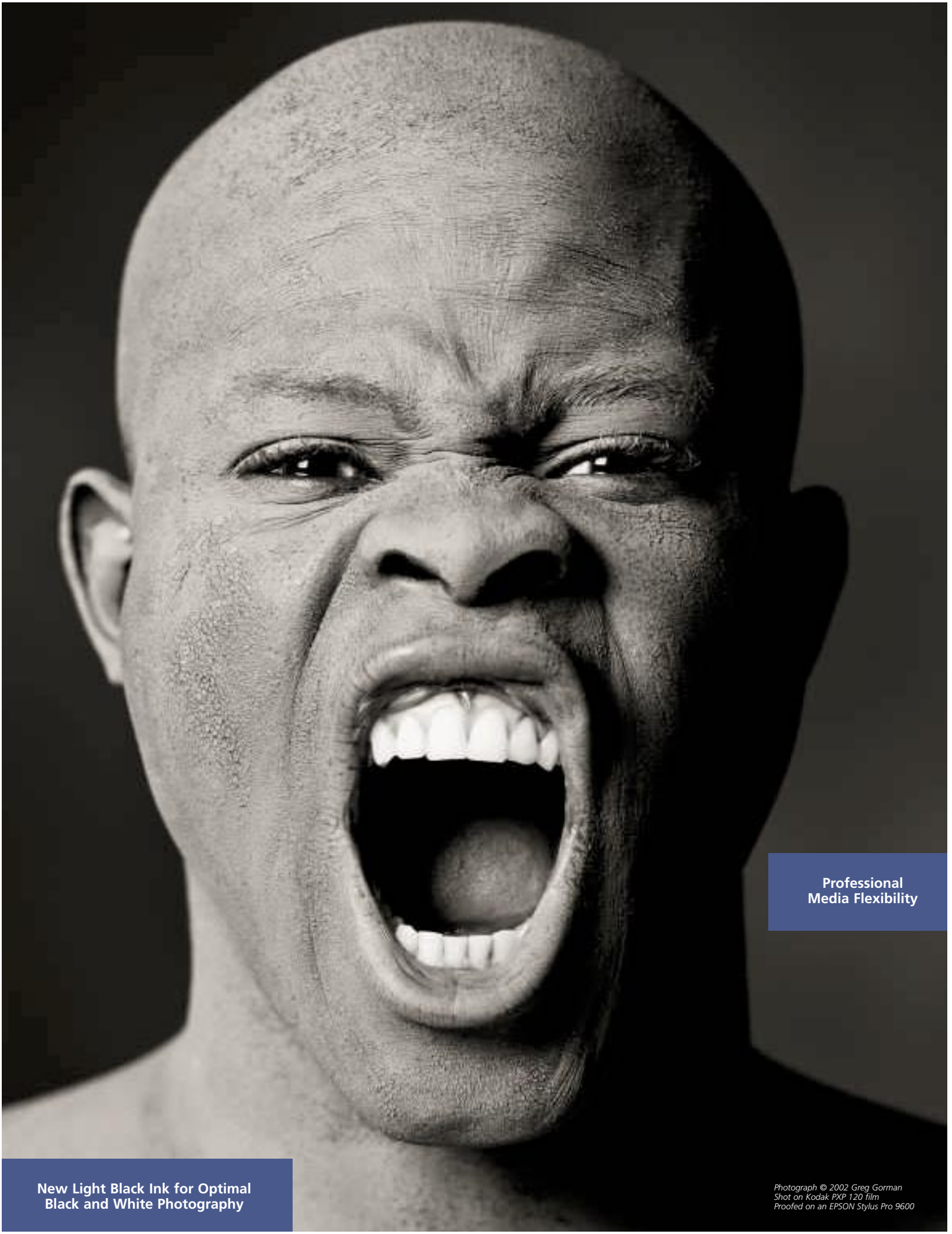
Printed on Recycled Paper

EPSON®

EPSON Stylus® Pro 7600 & 9600

Grand visions printed on a grand scale.

Photograph © 2002 Alberto Tolot
Shot on Portra VC 400 120 film
Proofed on an EPSON Stylus Pro 9600



Professional Media Flexibility

New Light Black Ink for Optimal Black and White Photography

Photograph © 2002 Greg Gorman
Shot on Kodak PXP 120 film
Proofed on an EPSON Stylus Pro 9600

The most desirable photographic printers ever produced by Epson.

Designed in collaboration with some of the world's best-known photographers and printmakers, the EPSON Stylus Pro 7600 and EPSON Stylus Pro 9600 printers incorporate technologies that have never before been available to large format printing professionals.

Representing advancements in ink, print head and print engine design, these next-generation, professional level 24-inch (SP7600) and 44-inch (SP9600) printers will produce some of the world's most exciting photographic prints.

EPSON UltraChrome Ink – a true milestone in pigmented ink technology – can produce color prints with a color gamut approaching today's standard dye ink technologies. And for the first time, produce professional level black and white prints capable of pleasing the most demanding black and white photographers.

To take full advantage of this remarkable ink technology, Epson has developed a brand new Micro Piezo DX3™ print head that can produce an astonishing resolution of 2880 x 1440 dpi.

Designed specifically for 7-color printing, Epson's most advanced print head delivers a level of photographic quality that must be seen to be believed.

A brand new print engine design capable of handling virtually any media type either 24-inch or 44-inch wide also incorporates innovative ideas that include true BorderFree™ printing, intelligent high-capacity ink systems, easy loading ink and media, and fast print speeds.

Backed by one of the most comprehensive warranty programs in the industry, the EPSON Stylus Pro 7600 and 9600 come with toll-free technical support Monday through Saturday, and usually next-business-day on-site service for a year. So should you need us, we'll be there.

Epson has once again set the standard for professional level photographic printing. Never before have creative professionals had such a powerful tool allowing them to produce their vision without compromise.

Whether for your own enjoyment or for resale, photographic prints produced by this breakthrough technology will forever change your perception of digital printmaking.

Photograph © 2002 Macduff Everton
Shot on Fuji NHGII 120 film
Proofed on an EPSON Stylus Pro 7600

Built-i
with Bo

EPSON UltraChrome Ink Technology

All New 7-Color Pigmented Inking System

- Extremely wide color gamut rivaling EPSON Photographic Dye inks
- Produces stable, long lasting photographic prints that are of resale quality

New Light Black Ink for Superior Photographic Reproduction

- Significantly improves the printer's gray balance while eliminating color casts
- Dramatically improves the midtones and highlights for smoother photographic transitions
- Reduces the metamerism effect of pigmented ink chemistry
- Enhances the ICC profiling process for ColorSync™ workflows

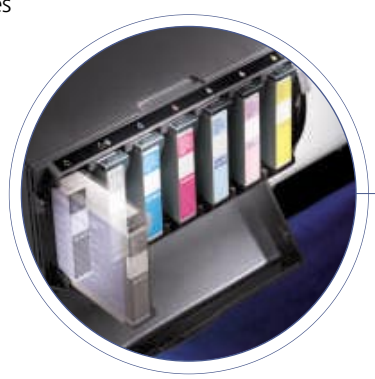
Professional Level Black and White Photographic Printing

- Produces a truly consistent image with no color crossover or color casts
- Produces neutral or toned black and white prints that satisfy a wide variety of photographers
- Depending upon media, produces a black D-max at up to 2.0

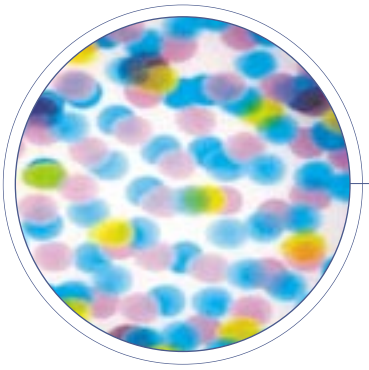
Three User-Exchangeable Black Ink Modes

By simply exchanging the black ink cartridge for another type, EPSON UltraChrome Ink technology lets you optimize your black ink density. Just choose between three different black ink modes to optimize the density for various media types and printing applications.

- **Photo Black Mode** is optimized for traditional photographic and ink jet coated media types, such as EPSON Premium Luster Photo, Photo Semi Gloss, and Premium Semimatte, to produce the highest level of photographic image quality
- **Matte Black Mode** is optimized for matte or plain medias, such as Enhanced Matte, Smooth and Textured Fine Art papers, as well as Somerset® Velvet for Epson, where the highest level of photographic image quality is desired
- **Dual Matte Black** is optimized for matte or plain media, like newsprint and plain bond paper, where print speed is favored over image quality



7-Color UltraChrome Ink
with an exclusive Light Black



True 2880 x 1440 dpi Resolution
with variable droplets as small as 4 picoliter
Microscopic Enlargement Shown Above

Auto Cutter
erFree Printing

Epson's Most Advanced Print Head Ever

True 2880 x 1440 dpi Resolution

- All-new print head can produce a single droplet as small as 4 picoliter
- Incredibly sharp text and line art that rivals a final press sheet
- Extremely fine blends and photographic transitions with no visible sign of ink jet technology

Variable Droplet Micro Piezo DX3 Technology

- Can produce up to three different dot sizes per print line, greatly decreasing print times while optimizing photographic quality
- Proprietary DX3 ASIC technology controls the printing process, resulting in consistent image quality and color output from print to print

EPSON Stylus Pro 7600
24" – shown with optional stand

Easy-to-use Cor
with backlight d
ink level indi

Photograph © 2002 Joe Carlson
Shot on VPL Type III (Process E-6) film
Proofed on an EPSON Stylus Pro 7600

EPSON Stylus Pro 9600
44" – stand included

Advanced Print Engine Technology

EPSON Intelligent High-Capacity Ink System

- Seven 110ml or 220ml ink cartridges (CcMmYKk) with automatic tracking of key data points such as ink levels, ink type and usage rates, for the most accurate production cost estimates
- Greatly increases productivity by replacing ink cartridges on the fly, even during the middle of a job, with no loss in image quality or production time
- EPSON Stylus Pro 9600 can use either 110ml or 220ml ink cartridge sizes at the same time to further optimize ink usage

Unsurpassed Media Flexibility

- Prints on virtually any media type, in roll or cut sheet, up to 24-inch or 44-inch wide
- Accurate automatic loading of cut sheet media up to 24-inch or 44-inch wide in a variety of weights up to 1.5mm thick
- User-adjustable Roll Media Spindle accepts either 2-inch or 3-inch media cores
- Built-in Automatic Cutting System and an optional Manual Media Cutter for cutting even the thickest of media types
- Optional Automatic Take-up Reel System for unattended production of large print runs (available on the EPSON Stylus Pro 9600 only)

True BorderFree Printing

- First ever wide-format print engine capable of printing off both left and right edges of the media, while automatically cutting top and bottom edges to produce a full-bleed print on all four sides depending on media type
- Built-in cutter will automatically cut top and bottom edges to either leave the page borders or bleed the image
- Fully trims your finished prints more accurately and safely than manual finishing techniques

High Performance Print Engine Speeds

- Depending on the print mode being used, print speeds will vary from 8 ft^2/hr to a maximum of 192 ft^2/hr
- Produces photographic quality printing at about 16 ft^2/hr
- Produces everyday "production-quality" output at about 87 ft^2/hr

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Superior Connectivity

- Includes one USB (1.1 and 2.0 compatible), one ECP Parallel and one Epson Expansion Slot for installing the optional internal IEEE 1394 FireWire® or 10/100 BaseT Ethernet cards
- Enhanced EPSON Photographic Drivers for Macintosh® and Windows® allowing for complete ink density control even when color management is turned off
- Optional EFI Fiery Spark Professional 2.0 Adobe® PostScript® 3 software RIP is available for professional pre-press proofing and other graphic design workgroups
- Fully supported by most leading third-party RIPs and workflows

EPSON Professional Ink Technologies[A]

Although EPSON UltraChrome Ink technology will become a new standard in professional ink systems, the EPSON Stylus Pro 7600 and 9600 are also available with EPSON Photographic Dye inks for those who have already built printing workflows using this award-winning ink technology.

- Available as a 6-color inking model (CcMmYKK), EPSON Photographic Dye Ink along with EPSON ColorLife™ Media will produce the highest level of photographic quality along with a lightfastness rating up to 26 years in color under glass[B]
- Preliminary data from Wilhelm Imaging Research, Inc. indicate the lightfastness of color UltraChrome prints made by the EPSON Stylus Pro 7600 and 9600 printers will be rated up to 100 years under glass on specific Epson media. Data indicate the lightfastness of black and white UltraChrome images printed using the 7-color mode will be rated as greater than 100 years under glass on specific Epson media[B]

EPSON Professional Media for Outstanding Image Quality

Epson Professional Media

UltraSmooth Fine Art Paper

For use with

Epson Stylus® Photo 2200
Epson Stylus Pro 4000
Epson Stylus Pro 7500
Epson Stylus Pro 7600
Epson Stylus Pro 9500
Epson Stylus Pro 9600
Epson Stylus Pro 10000
Epson Stylus Pro 10600

Product Information

Artists and professional photographers require true archival print media[1] in a variety of weights and surface textures for their digital fine art and photography. Now Epson brings you an acid free,100% cotton hot press paper that is coated on both sides for extra versatility.[2] This cylinder mould-made product features an ultra smooth finish on two sides that is optimized for Epson UltraChrome,™ and Epson Archival™ Ink.[1] Offered in a variety of sizes and formats, this fine art paper is not only acid, lignin, and chlorine free, it is also pH buffered with calcium carbonate for a true archival sheet.

Like all Epson's innovative media, this paper is engineered to give you the highest resolution and color saturation possible. As always, Epson supplies guarantee Epson quality.

1 For long term display, Epson recommends its UltraChrome ink or Epson Archival ink.
2 Cut-sheet is coated on two sides; roll version is single-sided.
3 Ink lightfastness rating, based on accelerated testing of prints on specialty media, displayed indoors, under glass. Actual print stability will vary according to media, printed image, display conditions, light intensity, humidity, and atmospheric conditions. Epson does not guarantee longevity of prints. For maximum print life, display all prints under glass or lamination or properly store them. Visit www.wilhelm-research.com for the latest information.

Features/Benefits

- 100% cotton hot press for long term durability
- Acid free and pH buffered to preserve fine art and photos
- Two sided coating on sheets for added versatility and value
- Natural white, ultra smooth surface for incredible detail and accurate reproduction
- Outstanding D-Max for prints with exceptional contrast
- Multiple weights, sizes, and formats for any fine art application
- Dries instantly for easy handling with Epson inks
- Over 100 years lightfastness[3] with Epson UltraChrome Ink

Feature Checklist

Feature	Performance	Additional Comments
Acid, lignin, and chlorine free, buffered	Preservation of fine art and photos	True archival quality
100% cotton rag	Long term durability	Fine art look and feel
Two sided coating (sheets)	Added versatility for presentation or portfolio	Perfect for portfolio work
Hot press, ultra smooth finish	Flat matte for sharp details and accurate reproduction	Mould–made
Natural white surface	High contrast	No optical brightening agents (OBA)
Dries instantly	Easy handling with Epson Inks	Less susceptible to scuffing

Epson Professional Media

UltraSmooth Fine Art Paper

Technical Specifications

	Roll	*Sheets*	*Sheets*
Basis Weights	250g/m²	325g/m²	500 g/m²
Thickness	15 mil	21 mil	30 mil
ISO Brightness	90%	90%	90%
Opacity	98%	98%	98%
Base Material	100% cotton rag	100% cotton rag	100% cotton rag
Surface finish	ultra smooth hot press	ultra smooth hot press	ultra smooth hot press
Core size (rolls)	3"	N/A	N/A
Spindle (rolls)	3" high tension	N/A	N/A

Driver Settings

For the following printers, ICC Profiles are posted at the Drivers and Downloads page at: www.prographics.epson.com
- Epson Stylus Pro 7500/9500/10000ARC/10600ARC
- Epson Stylus Pro 4000/7600/9600/10600 UltraChrome Ink (Matte Black)
- Epson Stylus Photo 2200 (Matte Black)

For the following printers select Watercolor Paper-Radiant White
- Epson Stylus Pro 4000/7600/9600/10600 UltraChrome Ink (Photo Black)

Operating Specifications

Required temperature for optimum performance	59° - 77° F 15° - 25° C
Required humidity for optimum performance	40% - 60% RH

Ordering Specifications

Product Code	*Product*	*UPC Code*
250g/m² (Single Sided)		
S041782-S	17" x 7' roll	0-10343-84933-4
S041782	24" x 50' roll	0-10343-84932-7
S041783	44" x 50' roll	0-10343-84934-1
325g/m² (Two Sided)		
SP91209	13" x 19" (25 sheets)	0-10343-84937-2*
SP91210	17" x 22" (25 sheets)	0-10343-84933-4*
500g/m² (Two Sided)		
SP91211-S	24" x 30" (3 sheets)	0-10343-84939-6
SP91211	24" x 30" (20 sheets)	0-10343-84938-9
SP91212	36" x 44" (10 sheets)	0-10343-84940-2*
SP91213	44" x 60" (10 sheets)	0-10343-84941-9*

* Expected to be available Spring 2004

EPSON

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Epson Canada, Ltd.
3771 Victoria Park Avenue, Toronto, Ontario M1W 3Z5

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ColorChecker® DC

Color Reference Chart

...the first

color reference chart

for digital photography

GretagMacbeth™

ColorChecker® DC

DIGITAL CAMERA COLOR REFERENCE CHART.
FROM GRETAGMACBETH.

Now for the first time, there's a color reference chart to match the sophistication of today's digital cameras. ColorChecker® DC Digital Camera Color Reference Chart — inspired by the success of the GretagMacbeth ColorChecker — features a broader color gamut with more color fields to help you get the best results from your digital camera.

Choice of visual or measurement comparisons

Check and correct by the numbers or by visual comparison in various image processing programs. Colorimetric reference values on CD are in CIELAB and XYZ based on 2° observer and D50 illumination.

Integration with ProfileMaker™ Color Management Software

Ensures accurate and precise ICC profiles with any digital camera. The result: increased picture quality and more efficient workflow.

White Balance with a digital camera

Large white patch (2.8 cm x 2.8 cm) in the center of the reference chart offers the ability to create an individual white balance.

ColorChecker DC Highlights:

- American legal format (21.59 cm x 35.56 cm)
- Contains 237 patches in a 12 cm x 20 cm grid
- 177 colors, including grayscale, grouped around white center point
- Each color patch measures 1.3 cm x 1.3 cm
- A series of black, gray, and white control patches around outer perimeter
- Registration marks support fast and precise cropping within ProfileMaker™ software
- Scale of 5 cm or 2.5 inches aids in capturing and further processing the image
- Can be measured with any manual spectrophotometer (ie.Spectrolino) to redefine reference values
- Can be used with all types of photographic and lighting conditions

CCS **Color Control Systems, Inc.**

Solutions for all your Color Control needs.

Color Control Systems, Inc.
1-800-793-8965

3537 Library Road
1-412-886-9208

Pittsburgh, PA 15234
FAX 1-412-886-9640

ColorChecker®

Image Reproduction Targets

YOUR COLOR. **PRECISELY.**

gmb GRETAGMACBETH

If your first shot isn't a ColorChecker, then you're not optimizing the power of your camera.

Professional photographers rely on GretagMacbeth ColorChecker® brand test targets to ensure accurate color reproduction – digital or film.

Why?

It's the fastest, easiest way to optimize even the most sophisticated film or digital camera.

Here's what ColorChecker can do for you:

- Achieve true-to-life color reproduction under any illumination
- Minimize tedious trial and error color adjustments
- Enable camera and studio lighting balance quickly and easily
- Allow instant gray balance

The fastest way to balance color and optimize lighting

The Original ColorChecker Standard

The 24-color array guarantees the most true-to-life image reproduction in any medium.

How?

Each of the 24 colors represents the actual color of natural objects such as blue sky, human skin, and foliage. And each color reflects light just like its real-world counterpart. But here's the amazing part... you can predict how the colors will reproduce under any illumination with any reproduction process!

The go-anywhere target!

Get ColorChecker precision in a handy pocket size. The Mini-ColorChecker... great for location shots!

The easiest way to deliver true-to-life color reproduction

ColorChecker Custom White Balance Chart

The ColorChecker Custom White Balance Chart delivers absolutely accurate white reproduction under any lighting condition. How? Most white balance targets aren't neutral. That means your camera shifts the way it reproduces white depending on the lighting conditions – warmer under indoor lighting, cooler under outdoor lighting and greener under fluorescent lighting. The ColorChecker Custom White Balance Chart is an absolute neutral white reference, so it prevents these shifts. The result... more true-to-life image reproduction.

3-Step Gray Scale

The ColorChecker 3-Step Gray Scale lets you instantly balance your images. A white, 18% gray and black target all on a single card make color adjustments faster and easier with your favorite photo processing software. Plus, the ColorChecker 3-Step Gray Scale makes studio lighting setup faster.

Scientifically developed to maximize the power of digital cameras

Digital ColorChecker SG

Nothing transforms the power of your digital camera like the Digital ColorChecker SG. It's the original ColorChecker and more - all in a single chart!

Here's what it can do for you:

- Compare your digital reproduction to a real-life scene or test target
- Create a white balance
- Profile your camera or input device

With 140 highly saturated, semi-gloss colors, you gain the widest color gamut for the most accurate ICC profiles. Plus, the chart works with our popular ProfileMaker 5 Photostudio and other camera profiling software.

ColorChecker Charts	Description
Custom White Balance Chart	Achieve accurate white reproduction in ambient light Size: 8.5 x 11 in. (21.59 x 27.94 cm)
3-Step Gray Scale Chart	Achieve realistic color with accurate white balance. Includes white, 18% gray and black targets. Enable quick color adjustments and faster studio lighting setup. Size: 8.5 x 11 in. (21.59 x 27.94 cm)
Original ColorChecker – 24-Patch Standard Chart	Reproduce true-to-life colors under any illumination with any medium. Includes 24 natural object colors Size: 8.5 x 11 in. (21.59 x 27.94 cm)
Digital ColorChecker -SG	Obtain the most accurate digital camera profiles 140 colors including: ▪ 17-step gray scale ▪ 24-patch original ColorChecker ▪ 14 unique skin tone colors Works with Profilemaker 5 Photostudio Size: 8.5 x 11 in. (21.59 x 27.94 cm)
Mini Versions– Standard 24- Patch, 3-Step Gray Scale, and White Balance	All of the above in a convenient pocket size: 3.25 x 2.25 in. (8.25 x 5.7 cm - 24-Patch) 4 x 6 in. (10.16 x 15.24 cm) - 3-Step Gray Scale and White Balance

Spectacular Color Made Easy!

ColorChecker products are the first step in consistent color reproduction. GretagMacbeth provides a complete range of color management solutions for the digital workflow. Call today for the solution that's right for you.
Visit www.gretagmacbeth.com

Gretag
holding accreditations from NAPL, I
accreditations and their associated practices and procedures.

echnology (NIST) as well as

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gmb GRETAGMACBETH

ProfileMaker 5

The evolution of professional color management

PM5 Photostudio

PM5 Publish

PM5 Publish Plus NEW

gretagmacbeth
YOUR COLOR. PRECISELY.

ProfileMaker 5 features individual modules that handle the various color imaging devices and processes in your workflow. Start small, choosing only the modules you need, with the freedom to add additional modules as your requirements change and grow.

- Monitor – calibrate and create ICC profiles for CRT, LCD and laptop displays, match multiple monitors to a reference monitor.
- Scanner – create ICC profiles for flatbed or drum scanners. Includes IT 8 target.
- Digital Camera – create ICC profiles for digital cameras. (Digital ColorChecker SG sold separately.)
- Printer – create ICC profiles for RGB, CMYK and Hexachrome® output devices.
- MultiColor Output – create profiles for Multicolor devices featuring CMYK plus up to 6 additional channels. Includes ability to set ink priorities, minimize ink consumption and minimize metamerism for two different illuminants. Includes Photoshop® Plug-Ins for soft/hard proofing and multicolor separations.
- Editor – edit profiles or fine tune the ones you've created working with lightness, contrast, saturation, white point or gradation curves. Check spot color reproducibility and view gamuts in 2D or 3D.
- ColorPicker – convert spot colors (CxF or Pantone) to process color individually or as a complete library. Limit the maximum number of device channels and define the minimum ink coverage for higher process stability.
- MeasureTool – collect, analyze and average data from color measurement devices for accurate profile computation. Create your own custom test charts to achieve the most accurate output profiles. Evaluate density, dot gain, gradation curves and color for complete process control.
- DeviceLink – create fully ICC compatible device linking workflows for RGB and CMYK color spaces and build direct connections between source and destination imaging devices to handle special applications like output to output transformations. Includes a new preserve black function plus clean black and clean primary options.
- Eye-One Process Control Bundle – includes Eye-One Pro measurement device and MeasureTool for measuring control strips like the Fogra Media step wedge in a convenient scan mode to determine values and tolerances. Measures proofs and prints against the reference step wedge and generates a detailed PDF report.

The Choice of Color Professionals

Professionals in color-critical environments worldwide have come to rely on ProfileMaker software to help them build high quality, reliable and customizable ICC profiles. These profiles connect the various steps in your color imaging workflow and put you on a direct route to accuracy and predictability.

ProfileMaker 5 expands upon this tradition of excellence with new features and enhancements that deliver even more expert level controls. Now it's even more intuitive and more efficient to build, edit and fine tune color profiles for all the devices – monitors, scanners, digital cameras, and all types of output devices – in your color imaging and reproduction workflow. New MultiColor solutions now extend far beyond RGB, CMYK and Hexachrome®!

Packaged solutions that match your workflow:

Professional
Color Management Solutions for

Digital Studio Photography

PM5 Photostudio creates high quality ICC profiles for all the devices used in a typical studio photography workflow including monitors, digital studio cameras, and RGB, CMYK and Hexachrome® output devices. Using these profiles, you'll be able to capture a broad gamut of colors, while minimizing retouching. Saves time and money, enhances output quality.

Professional
Color Management Solutions for

Publishing

PM5 Publish is designed specifically for prepress and publishing professionals that need optimal results from digital (laser, inkjet) and traditional (offset, flexo, gravure, etc.) printing systems. PM5 Publish provides the ability to profile monitors and scanners, as well as RGB, CMYK and Hexachrome® output devices. You can edit and customize profiles, while ensuring color quality for proofing and final print production.

NEW!

Professional
Color Management Solutions for

MultiColor Publishing

PM5 Publish Plus expands the gamut of digital printers, analog presses and LFP devices through the use of multicolor technology featuring CMYK plus up to six additional colors. It includes all the functionality of PM5 Publish, plus provides accurate, predictable color from concept to final production for CMYK+N based multicolor workflows. The six additional colors used in the separations can be selected without any restriction – defined based on spot measurements, manual Lab entries or from any of the PANTONE® libraries. PM5 MultiColor plug-in for Adobe® Photoshop® completes the solution by allowing 1-click separations plus the ability to softproof and hardproof your Lab, RGB and CMYK images.

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For detailed information visit www.gretagmacbeth.com

	Monitor	Scanner (Includes IT8 Target)	Digital Camera (Includes Digital ColorChecker SG)	Printer (RGB, CMYK, Hexachrome®, CMYK+RG, CMYK+RB)	Multicolor (CMYK + N)	Editor	ColorPicker	MeasureTool	DeviceLink	PM5 Multicolor Plugins for Adobe® Photoshop®
ProfileMaker Photostudio	●	○	●	●	○	●	●	◐	○	
ProfileMakerPublish	●	●	○	●	○	●	●	●	○	
ProfileMakerPublish Plus	●	●	○	●	●	●	●	●	○	●

Eye-One Bundle
Includes Eye-One Pro spectrophotometer with its semi-automated strip reading capabilities for high precision, low volume measuring and profile building. Eye-One Pro also measures emissive light for profiling CRT, LCD and laptop displays. In addition, Eye-One Pro can measure ambient light – letting you account for both flash and continuous light when building custom device profiles.

iCColor Bundle
Includes iCColor 210 automated spectral chart reader for higher volume measuring of test charts and for building accurate profiles for output devices. Also includes Eye-One Display 2 for profiling CRT, LCD and laptop displays.

Spectrolino/SpectroScan Bundle
Provides the highest level of automation and flexibility. Includes GretagMacbeth Spectrolino spectrophotometer for measuring spot color and profiling all types of monitors, as well as SpectroScan automatic x/y table for measuring test charts for profiling scanners and output devices.

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Mac

Windows®

● Standard

○ Optional

◐ Basic

*Provides ability to measure and save standard test chart data from any supported measurement device. Provides ability to compare measurement data and generate FOGRA media wedge reports when connected to a GretagMacbeth measurement device.

ACCURATE

FUNCTIONAL

FOCUSED

EXPANDABLE

ProfileMaker Photostudio, Publish, or **Publish Plus** make it more convenient and cost-effective than ever before to tailor a color management system to meet your needs. Each solution is designed to provide the most common functionality needed for your workflow. Additional modules can easily be added, giving you the flexibility to expand your package as your needs grow.

Options & modules available separately:
Monitor
Scanner
Digital Camera
Printer
Multicolor Output
Editor
ColorPicker
MeasureTool
DeviceLink
Eye-One Process Control bundle

Optional accessories:
Digital ColorChecker SG
IT8 Targets

Seeing is believing

IntelliStation T221 Flat Panel Monitor

IntelliStation Z Pro and SpaceBall® available separately

3D creativity by NVIDIA

Highlights • Models 9503-DG3/DG5

- ***Displays graphics-intensive applications with amazing clarity and realism approaching photographic quality***
- ***Wide 22.2"/564mm viewing area; 3840 x 2400 maximum addressability (9.2 million pixels)***
- ***48Hz refresh rate supports real-time video frame rates (Model 9503-DG5)***
- ***TFT LCD technology for wide-angle, flicker-free viewing***
- ***Firmware programmable for supported color matching systems***
- ***Backed by IBM service and support, as well as three-year limited warranty****

Critical visualization

Sharpen your view with the new IBM IntelliStation T221 Flat Panel Monitor. With a cinematic 16:10 aspect ratio and 204 pixels/inch, T221 images invite close scrutiny with fine-line accuracy, crisp contrast and subtle detail. Combining versatility with brilliant visual performance, the T221 offers an advanced digital interface that supports a wide range of recommended graphics adapters and IntelliStation Pro workstations. Choose your solution: order the T221 high-resolution monitor complete with a standard IntelliStation workstation configured with a certified NVIDIA® graphics adapter; or IBM will build a custom IntelliStation solution to your particular requirements. Either way, the T221 monitor will open your eyes to new possibilities.

Application-focused

Packing over 9.2 million pixels into its 22.2"/564mm viewing area, the T221 earns its place in a wide range of demanding settings including medical, scientific, digital content creation, engineering, oil exploration and other technical fields—anywhere image definition is decisive.

OpenGL spoken here

The visual fidelity of the T221—in clarity, detail, and breadth of information—qualifies it for the most demanding OpenGL 3D applications. Select the NVIDIA Quadro4 980 XGL or the new Quadro FX accelerators, featuring vertex and pixel programmability, full-scene antialiasing, and a 128-bit precision graphics pipeline.

Easy on the eyes

IBM TFT technology meets TCO95 standards with low electromagnetic emissions; a polarizing anti-glare coating; a wide viewing angle; low power consumption and ambient heat, all in a space-saving design. Set your sights on the IntelliStation T221 Flat Panel Monitor. Seeing *is* believing.

*See reverse for additional warranty information[1].

Choose IBM today | Go to **ibm.com** or call 1 888 SHOP IBM to buy direct, locate an IBM reseller or for more information.

IntelliStation T221 Flat Panel Monitor • Technical specifications • Models 9503-DG3/DG5

Part number	9503-DG3, 9503-DG 5 (both stealth black)
Certified graphics adapters	NVIDIA Quadro FX 3000/2000/1000, Quadro4 980 XGL (all 8X AGP)
Screen	
Technology	Active Matrix Thin-Film-Transistor (TFT) Liquid Crystal Display (LCD) Dual Domain In-Plane Switching (IPS)
Size/viewable image size	22.2"/22.2" [564mm]
Pixel pitch	0.1245mm
Display colors (maximum)	Up to 16.7 million colors
Brightness	235 (cd/m^2)
Contrast ratio	400:1
Functional features[2]	
Display modes	QUXGA-W (quad stripe/tile and dual stripe modes) VGA, SVGA, XGA, SXGA & UXGA
Maximum addressability	3840x2400
Active display area (Horizontal x Vertical)	18.8"x11.8" [478x299mm]
Viewing angle	+/-85° up, down; +/-85° left, right
Power management	ENERGY STAR[3]
User controls	Power, brightness, video configuration, information
On-screen display (OSD)	Yes
Plug & Play	VESA DDC 2B
Compatibility	For the most up-to-date compatibility information, visit **ibm.com**/support
Physical features	
Power supply	90-137V AC, 180-265V AC
Signal cable (provided)	2-1.8m; each cable configured with 2 DVI-D connectors (4 DVI total); 9503-DG5 includes separate dual-link DVI converter plus cables
Dimensions (HxWxD)	17.2"x21.5"x7.7" [437x547x196mm]
Weight	26.4 lb [12 kg]
Tilt	5° forward, 30° backward
Portrait/Landscape	Landscape only (VESA mounting also provided)
Operating environment	0-35°C, 8-80% Humidity
Storage environment	-20-60°C, 5-95% Humidity
Power consumption	<150W (typical)
Regulatory approvals	UL, CSA, IEC/EN60950, CE, FCC Class A, VCCI Class A, MPR 2, MPR 3 (Category A), TCO95
Limited warranty[1] (parts/labor/backlight)	3 years

Environment	Application	Audience
Engineering	Use high-resolution 3D CAD digital images instead of hand-built prototypes to shorten development cycles	Automotive, aerospace, and industrial design CAD/CAM
Finance	Replace multiple monitors with a single sleek T221 on the trading desk or in the back office	Banks, trading floors
Publishing	Display two full-size, side-by-side A4 and/or letter-size pages without loss of content; enhances productivity by reducing the need to pan, scroll and zoom	Digital museums, pre-press, maintenance and service providers
Earth resource management	Create and analyze complex visualizations of geophysical surface and subsurface data; supplements HIVEs with collaboration on your desktop	Petroleum industry, government agencies, GIS (mapping, visualization)
Digital content creation	Display and work with digital images that approach film-quality realism at up to full widescreen; 48Hz refresh rate supports real-time video frame rate. Firmware programmable for supported color matching systems	Image compositing, HD video editing, digital effects, collaborative viewing
Medicine	View digitally captured x-rays; collaborate electronically with experts around the world	Hospitals, doctors' offices, insurance companies

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[1] For information regarding IBM's Statement of Limited Warranty, call 1 800 772-2227 or contact your reseller. Copies available upon request. With respect to on-site service, a technician is sent after IBM attempts to resolve the problem remotely.

[2] Requires attachment to a suitably configured system with similarly enabled operating system software.

[3] As an ENERGY STAR partner, IBM has determined that this product meets the ENERGY STAR guidelines for energy efficiency.

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Image Processing Toolbox 5

Perform image processing, analysis, visualization, and algorithm development

The Image Processing Toolbox provides a comprehensive set of reference-standard algorithms and graphical tools for image processing, analysis, visualization, and algorithm development. You can restore noisy or degraded images, enhance images for improved intelligibility, extract features, analyze shapes and textures, and register two images. Most toolbox functions are written in the open MATLAB® language. This means that you can inspect the algorithms, modify the source code, and create your own custom functions.

The Image Processing Toolbox supports engineers and scientists in areas such as biometrics, remote sensing, surveillance, gene expression, microscopy, semiconductor testing, image sensor design, color science, and materials science. It also facilitates the learning and teaching of image processing techniques.

Working with the Image Processing Toolbox

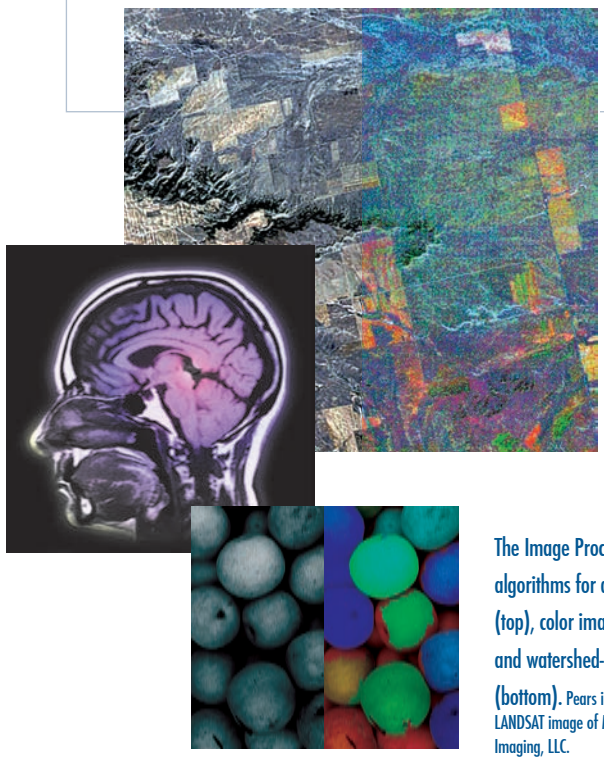
The Image Processing Toolbox supports images generated by a wide range of devices, including digital cameras, frame grabbers, satellite and airborne sensors, medical imaging devices, microscopes, telescopes, and other scientific instruments. You can visualize, analyze, and process these images in many data types, including single- and double-precision floating-point and signed or unsigned 8-, 16-, and 32-bit integers.

Importing and Exporting Images

There are several ways to import or export images into and out of the MATLAB environment for processing. You can use the Image Acquisition Toolbox (available separately) to acquire live images from Web cameras, frame grabbers, DCAM-compatible cameras, and other devices. Using the Database Toolbox (also available separately), you can access images stored in ODBC/JDBC-compliant databases.

KEY FEATURES

- Image enhancement, including linear and nonlinear filtering, filter design, deblurring, and automatic contrast enhancement
- Image analysis, including texture analysis, line detection, morphology, edge detection, segmentation, region-of-interest (ROI) processing, and feature measurement
- Color image processing, including color space conversions and device-independent ICC profile import and export
- Spatial transformations and image registration, including a graphical tool for control-point selection
- Image transforms, including FFT, DCT, Radon, and fan-beam projection
- DICOM import and export
- Interactive image display and modular tools for building image GUIs
- Support for multidimensional image processing



The Image Processing Toolbox includes algorithms for decorrelation stretching (top), color image processing (center), and watershed-based segmentation (bottom). Pears image courtesy of Corel. LANDSAT image of Montana courtesy of Space Imaging, LLC.

MATLAB supports standard data and image formats, including JPEG, TIFF, PNG, HDF, HDF-EOS, FITS, Microsoft Excel, ASCII, and binary files. It also supports multiband image formats, such as LANDSAT. Low-level I/O functions enable you to develop custom routines for working with any data format.

For medical imaging, the Image Processing Toolbox supports the DICOM file format. You can read and write DICOM images and associated metadata and create custom data dictionaries in MATLAB.

Pre- and Post-Processing Images

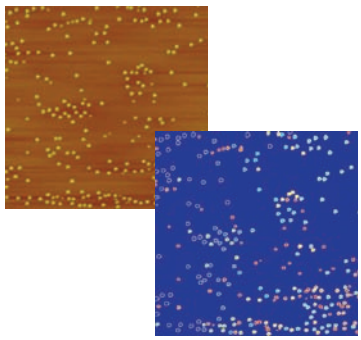
The Image Processing Toolbox provides reference-standard algorithms for pre- and post-processing tasks that solve frequent system problems, such as interfering noise, low dynamic range, out-of-focus optics, and the difference in color representation between input and output devices.

Enhancing Images

Image enhancement techniques in the Image Processing Toolbox enable you to increase the signal-to-noise ratio and accentuate image features by modifying the colors or intensities of an image. You can:

- Perform histogram equalization
- Perform decorrelation stretching
- Remap the dynamic range
- Adjust the gamma value
- Perform linear, median, or adaptive filtering

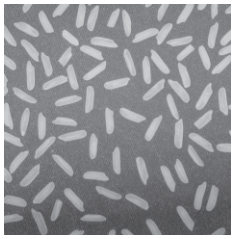
The toolbox includes specialized filtering routines and a generalized multidimensional filtering function that handles integer image types, multiple boundary padding options, and convolution and correlation. Predefined filters and functions for designing and implementing your own linear filters are also provided.



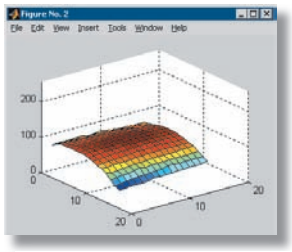
WATERSHED SEGMENTED IMAGE

Image courtesy of Ian Farrer, University of Cambridge.

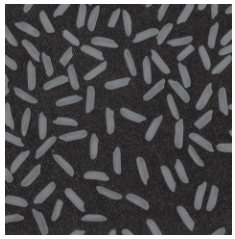
Atomic force microscope image of quantum semiconductor dots formed during the deposition of indium arsenide onto gallium arsenide (left) and the image segmented using the watershed transform in the Image Processing Toolbox (right).



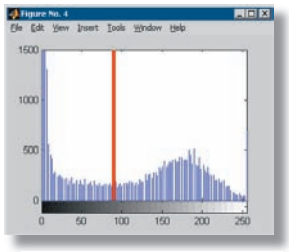
Original image of rice grains with nonuniform background intensity.



Extraction of nonuniform background intensity using morphological opening.

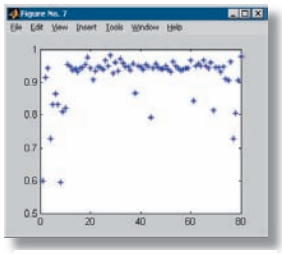


Result of subtraction of nonuniformity from original.

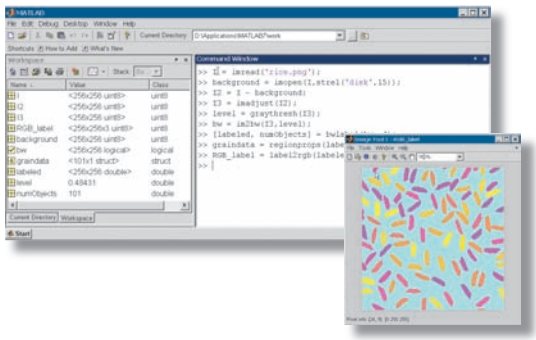


Histogram plot of resultant image with automatic thresholding.

Binary thresholded image.



Measuring region properties, such as the eccentricity of the rice grains.



A typical interactive session using MATLAB and the Image Processing Toolbox to perform connected components analysis on an image with nonuniform background intensity.

Deblurring Images

The Image Processing Toolbox supports several fundamental deblurring algorithms, including blind, Lucy-Richardson, Wiener, and regularized filter deconvolution, as well as conversions between point spread and optical transfer functions. These functions help correct blurring caused by out-of-focus optics, movement by the camera or the subject during image capture, atmospheric conditions, short exposure time, and other factors. All deblurring functions work with multidimensional images.

Managing Device-Independent Color

The Image Processing Toolbox enables you to accurately represent color independently from input and output devices. This is useful when developing algorithms for several different devices or when analyzing the characteristics of a particular device. Specialized functions in the toolbox let you:

- Convert images between color spaces, such as RGB, sRGB, YCrCb, XYZ, Lab, and HSV
- Import n-dimensional ICC color profiles to convert images to a device-independent color space
- Create new ICC color profiles for specific input and output devices
- Apply user-defined colormaps to RGB images to reduce the number of colors

Image Transforms

Transforms such as the FFT and the DCT play a critical role in many image processing tasks, including image enhancement, analysis, restoration, and compression. The Image Processing Toolbox provides several image transforms, including the DCT, Radon, and fan-beam projection. You can use the inverse Radon transform to reconstruct images from parallel-beam and fan-beam projection data (common in tomography applications). Image transforms are also available in MATLAB and in the Wavelet Toolbox (available separately).

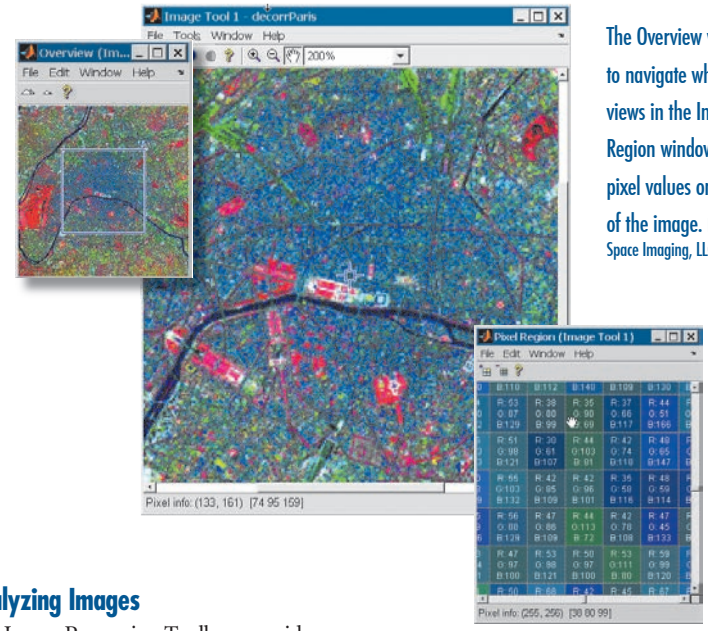


Image Tool 1 - decorrParis
File Tools Window Help
Overview (Im...
File Edit Window Help
200%
Pixel info: (133, 161) [74 95 159]
Pixel Region (Image Tool 1)
File Edit Window Help
Pixel info: (255, 256) [30 80 99]

The Overview window (top left) is used to navigate when looking at magnified views in the Image Tool (center). The Pixel Region window (bottom) superimposes pixel values on a highly magnified view of the image. LANDSAT image of Paris courtesy of Space Imaging, LLC.

Analyzing Images

The Image Processing Toolbox provides a comprehensive suite of reference-standard algorithms and graphical tools for image analysis tasks such as statistical analysis, feature extraction, and property measurement.

Statistical functions let you analyze the general characteristics of an image by:

- Computing the mean or standard deviation
- Determining the intensity values along a line segment
- Displaying an image histogram or plotting a profile of intensity values

Edge-detection algorithms let you identify object boundaries in an image. These algorithms include the Sobel, Prewitt, Roberts, Canny, and Laplacian of Gaussian methods. The powerful Canny method can detect true weak edges without being "fooled" by noise.

Image segmentation algorithms determine region boundaries in an image. You can explore many different approaches to image segmentation, including automatic thresholding, edge-based methods, and morphology-based methods such as the watershed transform, often used to segment touching objects.

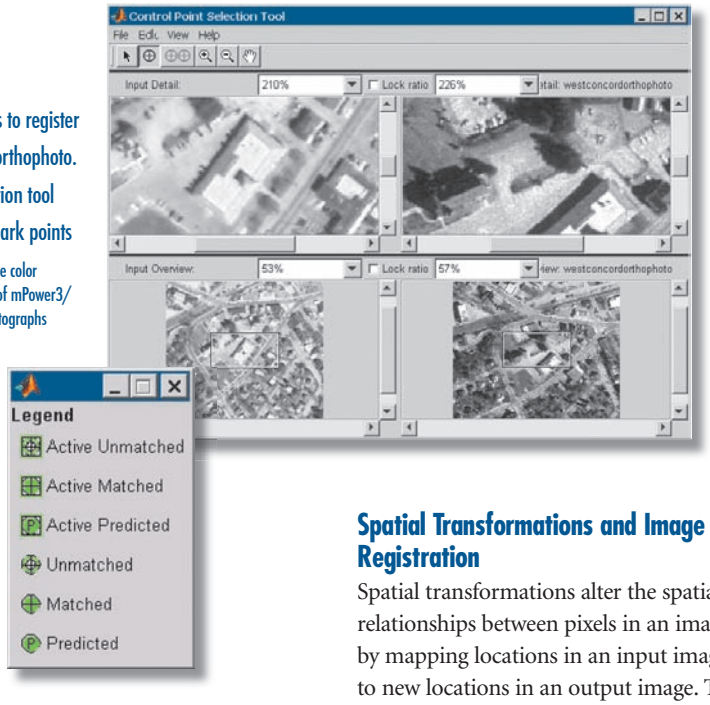
Morphological operators enable you to detect edges, enhance contrast, remove noise, segment an image into regions, thin regions, or perform skeletonization on regions.

Morphological functions in the Image Processing Toolbox include:

- Hole filling
- Peak and valley detection
- Watershed segmentation
- Reconstruction
- Distance transform

The Image Processing Toolbox also contains advanced image analysis functions that let you:

- Measure the properties of a specified image region, such as the area, center of mass, and bounding box
- Detect lines and extract lines segments from an image using the Hough transform
- Measure properties, such as surface roughness or color variation, using texture analysis functions



Choosing control points to register an aerial photo to an orthophoto. The control point selection tool helps you select landmark points and align images. Visible color aerial photographs courtesy of mPower3/Emerge. Orthoregistered photographs courtesy of MassGIS.

Visualizing Images

The Image Processing Toolbox provides an integrated environment for interactive image display and exploration. You can load an image from a file or from the MATLAB workspace, adjust the contrast, examine a region of pixels, view image information, zoom and pan around the image, and track your location in a large image using an overview window. The image display environment is modular and open, enabling you to customize the tools provided and add your own.

MATLAB visualization tools let you represent the information in your image data as histograms, contour plots, montages, pixel profiles, transparent overlays, and images that are texture-mapped onto surfaces. You can view and measure image attributes, such as the location and value of pixels in an image, or display color bars to view the mapping of colors to values. Volume visualization tools in MATLAB let you create isosurface displays of multidimensional image data sets.

Spatial Transformations and Image Registration

Spatial transformations alter the spatial relationships between pixels in an image by mapping locations in an input image to new locations in an output image. The Image Processing Toolbox supports common transformational operations, such as resizing, rotating, and interactive cropping of images, as well as geometric transformations with arbitrary-dimensional arrays.

Image registration is important in remote sensing, medical imaging, and other applications where images must be aligned to enable quantitative analysis. Using the Image Processing Toolbox, you can interactively select points in a pair of images and align the two images by performing a spatial transformation, such as linear conformal, affine, projective, polynomial, piecewise linear, or local weighted mean.

Developing Algorithms

MATLAB and the Image Processing Toolbox provide a comprehensive platform for interacting with image data and developing image processing algorithms. The toolbox adds reference-standard image processing and analysis algorithms and image-specific graphical tools to the high-level language, basic mathematical functions, development tools, and visualization capabilities of MATLAB.

Required Products

MATLAB

Related Products

Image Acquisition Toolbox. Acquire images and video from industry-standard hardware

Mapping Toolbox. Analyze and visualize geographic information

Signal Processing Toolbox. Perform signal processing, analysis, and algorithm development

Video and Image Processing Blockset. Design and simulate video and image processing systems and components

Platform and System Requirements

For platform and system requirements, visit *www.mathworks.com/products/image/* ■

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MATLAB® 7

The Language of Technical Computing

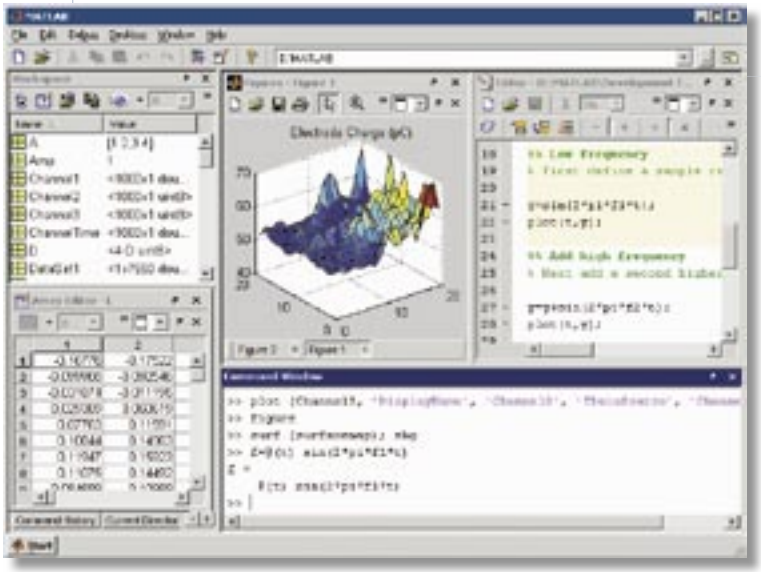
MATLAB® is a high-level technical computing language and interactive environment for algorithm development, data visualization, data analysis, and numerical computation. Using MATLAB, you can solve technical computing problems faster than with traditional programming languages, such as C, C++, and Fortran.

You can use MATLAB in a wide range of applications, including signal and image processing, communications, control design, test and measurement, financial modeling and analysis, and computational biology. Add-on toolboxes (collections of special-purpose MATLAB functions, available separately) extend the MATLAB environment to solve particular classes of problems in these application areas.

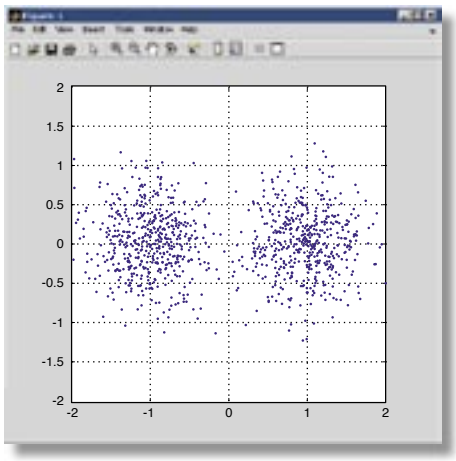
MATLAB provides a number of features for documenting and sharing your work. You can integrate your MATLAB code with other languages and applications, and distribute your MATLAB algorithms and applications.

KEY FEATURES

- High-level language for technical computing
- Development environment for managing code, files, and data
- Interactive tools for iterative exploration, design, and problem solving
- Mathematical functions for linear algebra, statistics, Fourier analysis, filtering, optimization, and numerical integration
- 2-D and 3-D graphics functions for visualizing data
- Tools for building custom graphical user interfaces
- Functions for integrating MATLAB based algorithms with external applications and languages, such as C, C++, Fortran, Java, COM, and Microsoft Excel



The MATLAB environment lets you develop algorithms, interactively analyze data, view data files, and manage projects.



```
% Generate a
vector of N bits
N = 1024;
Bits = rand(N,1)>0.5;

% Convert to symbols
Tx = 1-2*Bits;

% Add white Gaussian noise
P = 0.4;
Nz = P*(randn(N,1)+i*randn(N,1));
Rx = Tx + Nz;

% Display constellation
plot(Rx,'.');
axis([-2 2 -2 2]);
axis square, grid;
```

A communications modulation algorithm that generates 1,024 random bits, performs modulation, adds complex Gaussian noise, and plots the result–all in just 9 lines of MATLAB code.

Developing Algorithms and Applications

MATLAB provides a high-level language and development tools that let you quickly develop and analyze your algorithms and applications.

The MATLAB Language

The MATLAB language supports the vector and matrix operations that are fundamental to engineering and scientific problems. It enables fast development and execution.

With the MATLAB language, you can program and develop algorithms faster than with traditional languages because you do not need to perform low-level administrative tasks, such as declaring variables, specifying data types, and allocating memory. In many cases, MATLAB eliminates the need for 'for' loops. As a result, one line of MATLAB code can often replace several lines of C or C++ code.

At the same time, MATLAB provides all the features of a traditional programming language, including arithmetic operators, flow control, data structures, data types, object-oriented programming (OOP), and debugging features.

MATLAB lets you execute commands or groups of commands one at a time, without compiling and linking, enabling you to quickly iterate to the optimal solution.

For fast execution of heavy matrix and vector computations, MATLAB uses processor-optimized libraries. For general-purpose scalar computations, MATLAB generates machine-code instructions using its JIT (Just-In-Time) compilation technology.

This technology, which is available on most platforms, provides execution speeds that rival those of traditional programming languages.

Development Tools

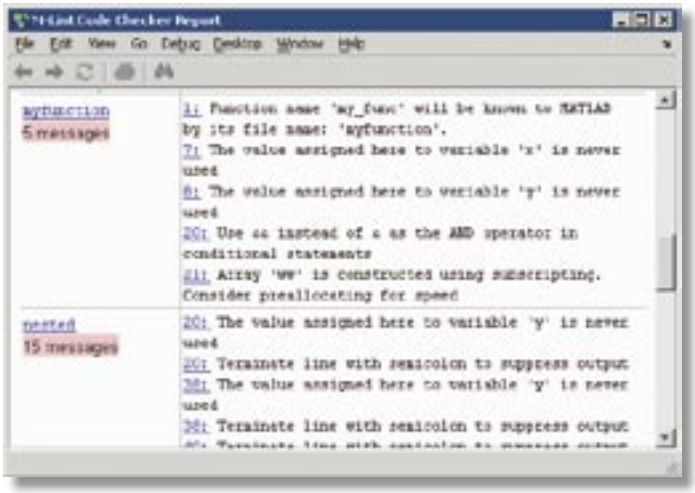
MATLAB includes development tools that help you implement your algorithm efficiently. These include the following:

MATLAB Editor—Provides standard editing and debugging features, such as setting breakpoints and single stepping

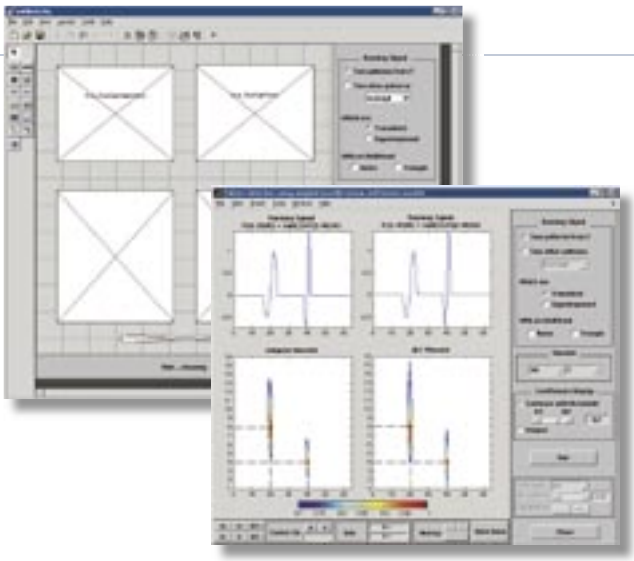
M-Lint Code Checker—Analyzes your code and recommends changes to improve its performance and maintainability

MATLAB Profiler—Records the time spent executing each line of code

Directory Reports—Scan all the files in a directory and report on code efficiency, file differences, file dependencies, and code coverage



An M-Lint Code Checker report that includes recommendations for making the code faster and easier to maintain.



GUIDE layout of a wavelet analysis GUI (top) together with the completed interface (bottom).

HDF data from a satellite, selected and imported into MATLAB using the MATLAB HDF Import Tool.

Designing Graphical User Interfaces

You can use the interactive tool GUIDE (Graphical User Interface Development Environment) to lay out, design, and edit user interfaces. GUIDE lets you include list boxes, pull-down menus, push buttons, radio buttons, and sliders, as well as MATLAB plots and ActiveX controls. Alternatively, you can create GUIs programmatically using MATLAB functions.

Analyzing and Accessing Data

MATLAB supports the entire data analysis process, from acquiring data from external devices and databases, through preprocessing, visualization, and numerical analysis, to producing presentation-quality output.

Data Analysis

MATLAB provides interactive tools and command-line functions for data analysis operations, including:

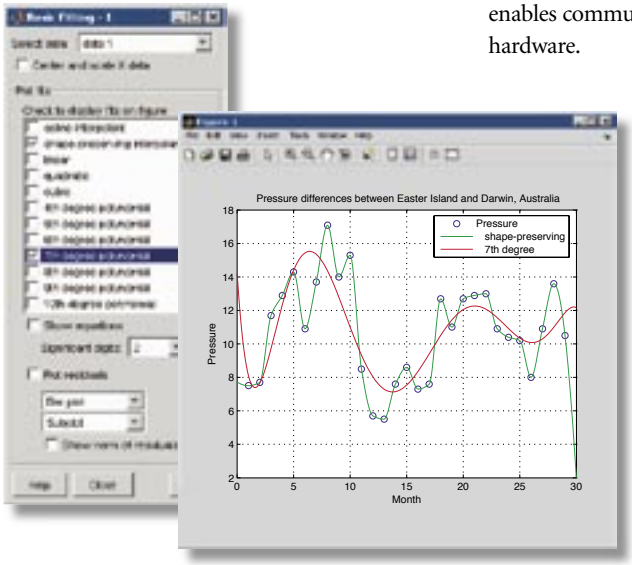
- Interpolating and decimating
- Extracting sections of data, scaling, and averaging
- Thresholding and smoothing
- Correlation, Fourier analysis, and filtering
- 1-D peak, valley, and zero finding
- Basic statistics and curve fitting
- Matrix analysis

Data Access

MATLAB is an efficient platform for accessing data from files, other applications, databases, and external devices. You can read data from popular file formats, such as Microsoft Excel; ASCII text or binary files; image, sound, and video files; and scientific files, such as HDF and HDF5. Low-level binary file I/O functions let you work with data files in any format. Additional functions let you read data from Web pages and XML.

You can call other applications and languages, such as C, C++, COM objects, DLLs, Java, Fortran, and Microsoft Excel, and access FTP sites and Web services. Using the Database Toolbox, you can also access data from ODBC/JDBC-compliant databases.

You can acquire data from hardware devices, such as your computer's serial port or sound card. Using the Data Acquisition Toolbox, you can stream live, measured data directly into MATLAB for analysis and visualization. The Instrument Control Toolbox enables communication with GPIB and VXI hardware.



Plot showing curve fitted to the monthly averaged atmospheric pressure differences between Easter Island and Darwin, Australia.

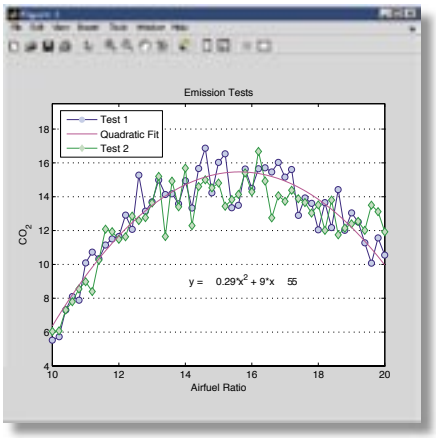
Visualizing Data

All the graphics features that are required to visualize engineering and scientific data are available in MATLAB. These include 2-D and 3-D plotting functions, 3-D volume visualization functions, tools for interactively creating plots, and the ability to export results to all popular graphics formats. You can customize your plots by adding multiple axes; changing line colors and markers; adding annotation, LaTEX equations, and legends; and drawing shapes.

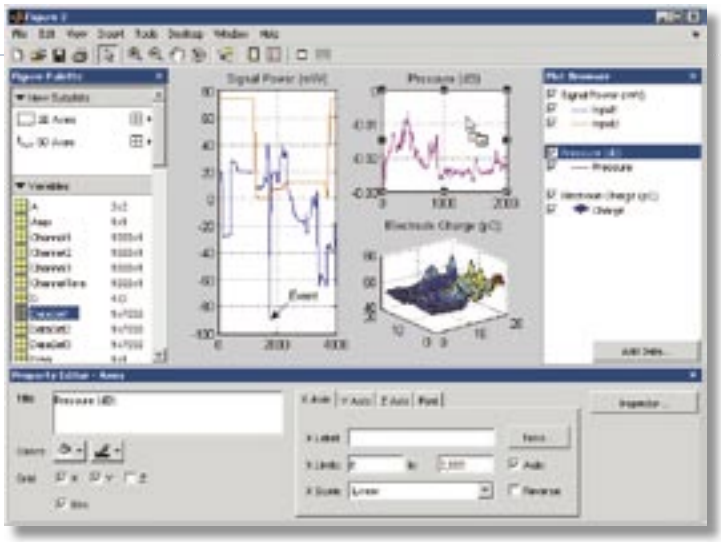
2-D Plotting

You can visualize vectors of data with 2-D plotting functions that create:

- Line, area, bar, and pie charts
- Direction and velocity plots
- Histograms
- Polygons and surfaces
- Scatter/bubble plots
- Animations



Line plots of multiple engine emission test results, with a curve fitted to the raw data.

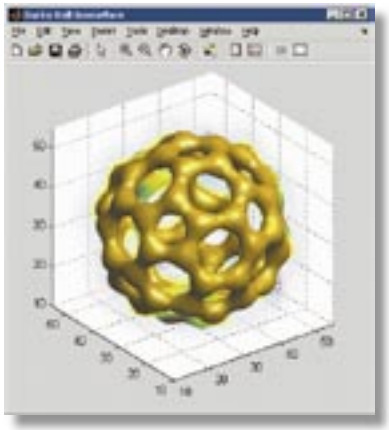


A collection of graphs, constructed interactively by dragging data sets onto the plot window, creating new subplots, changing properties such as colors and fonts, and adding annotation.

3-D Plotting and Volume Visualization

MATLAB provides functions for visualizing 2-D matrices, 3-D scalar, and 3-D vector data. You can use these functions to visualize and understand large, often complex, multidimensional data. You can specify plot characteristics, such as camera viewing angle, perspective, lighting effect, light source locations, and transparency. 3-D plotting functions include:

- Surface, contour, and mesh
- Image plots
- Cone, slice, stream, and isosurface



A 3-D isosurface plot revealing the geodesic dome structure of a carbon-60 fullerene molecule.

Creating and Editing Plots Interactively

MATLAB provides interactive tools for designing and modifying graphics. From a MATLAB figure window, you can perform the following tasks:

- Drag and drop new data sets onto the figure
- Change the properties of any object on the figure
- Zoom, rotate, pan, and change camera angle and lighting
- Add annotations and data tips
- Draw shapes
- Generate an M-code function that can be reused with different data

Importing and Exporting Graphic Files

MATLAB lets you read and write common graphical and data file formats, such as GIF, JPEG, BMP, EPS, TIFF, PNG, HDF, AVI, and PCX. As a result, you can export MATLAB plots to other applications, such as Microsoft Word and Microsoft PowerPoint, or to desktop publishing software. Before exporting, you can create and apply style templates, covering characteristics such as layout, font, and line thickness, to meet publication specifications.

Performing Numeric Computation

MATLAB contains mathematical, statistical, and engineering functions to support all common engineering and science operations. These functions, developed by experts in mathematics, are the foundation of the MATLAB language. The core math functions use the LAPACK and BLAS linear algebra subroutine libraries and the FFTW Discrete Fourier Transform library. Because these processor-dependent libraries are optimized to the different platforms that MATLAB supports, they execute faster than the equivalent C or C++ code.

MATLAB provides the following types of functions for performing mathematical operations and analyzing data:

- Matrix manipulation and linear algebra
- Polynomials and interpolation
- Fourier analysis and filtering
- Data analysis and statistics
- Optimization and numerical integration
- Ordinary differential equations
- Partial differential equations
- Sparse matrix operations

MATLAB can perform arithmetic on a wide range of data types, including doubles, singles, and integers.

Add-on toolboxes (available separately) provide specialized mathematical computing functions for areas including signal processing, optimization, statistics, symbolic math, partial differential equation solving, and curve fitting.

Publishing Results and Deploying Applications

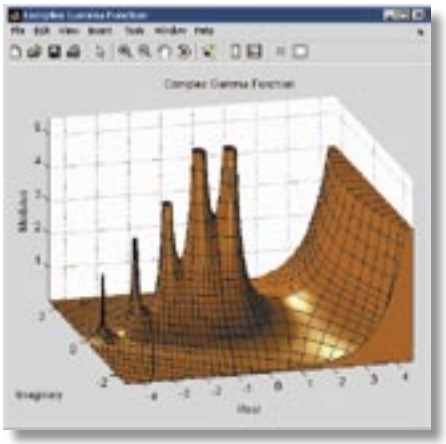
MATLAB provides a number of features for documenting and sharing your work. You can integrate your MATLAB code with other languages and applications and deploy your MATLAB algorithms and applications as stand-alone programs or software modules.

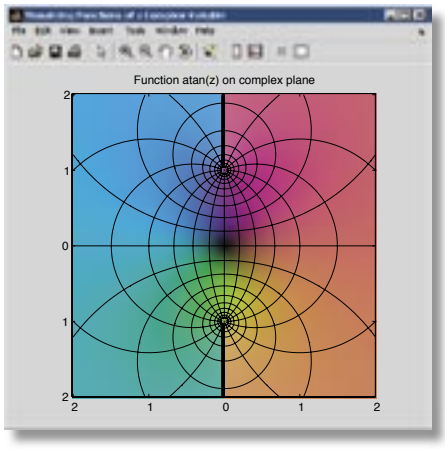
Publishing Results

MATLAB lets you export your results as plots or as complete reports. You can export plots to all popular graphics file formats and then import them into other packages, such as Microsoft Word or Microsoft PowerPoint. Using the MATLAB Editor, you can automatically publish your MATLAB code in HTML, Word, LaTEX, and other formats.

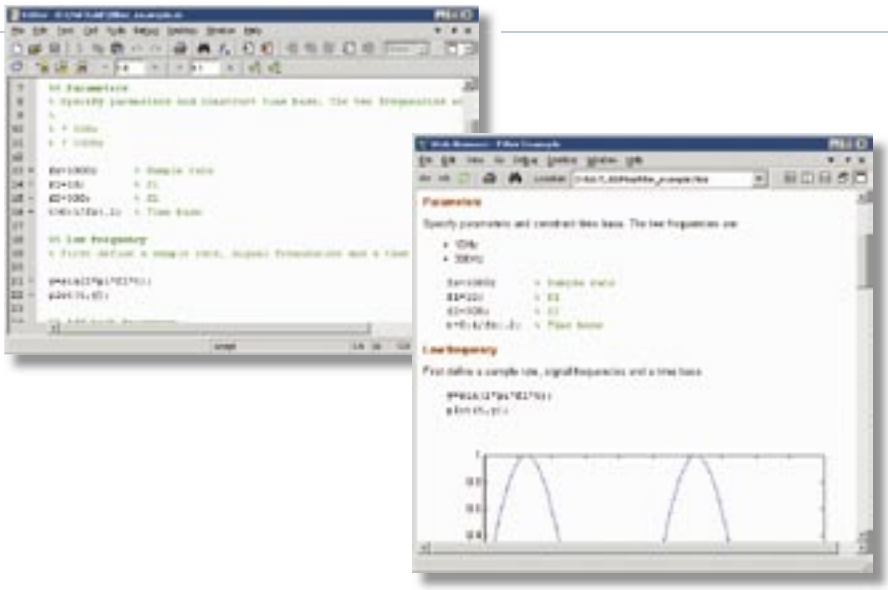
To create more complex reports, such as simulation runs and multiple parameter tests, you can use the MATLAB Report Generator (available separately).

Plot showing the complex valued gamma function on the complex plane, where the height of the surface is the modulus, or absolute value, and the contour lines are modulus and phase.





Plot of complex function `atan(z)`. Contour lines for the real and imaginary parts are superimposed on a color image showing magnitude and phase.



M-code program (left) published to HTML (right) using the MATLAB Editor. Results output to the command window or to plots are captured and included, and the comments are turned into section headings and body text in the HTML.

Integrating MATLAB Code with Other Languages and Applications

MATLAB provides functions for integrating C and C++ code, Fortran code, COM objects, and Java code with your applications. You can call DLLs, Java classes, and ActiveX controls. Using the MATLAB engine library, you can also call MATLAB from C, C++, or Fortran code.

Deploying Applications

You can create your algorithm in MATLAB and distribute it to other MATLAB users as M-code.

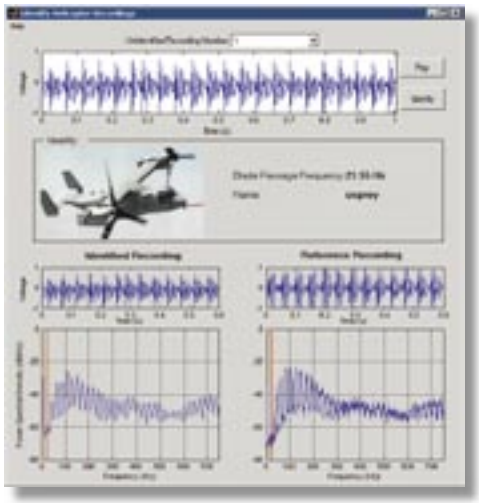
Using the MATLAB Compiler (available separately), you can deploy your algorithm, as a stand-alone application or as a software module that you include in your project, to users who do not have MATLAB.

Additional products let you convert your algorithm into a software module that is callable from COM, or Microsoft Excel.

Platform and System Requirements

For platform and system requirements, visit *www.mathworks.com/products/matlab*

Helicopter sound identification application, deployed and running outside MATLAB. The application, developed in MATLAB, directly acquires signals from measurement hardware, performs analysis and plotting, and includes GUI controls.



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MATLAB [1]	1,900
NEW Distributed Computing Toolbox [23, 24]	1,000
NEW MATLAB Distributed Computing Engine [25, 26]	*see MATLAB Distributed Computing Engine price list*
Math and Optimization	
Optimization Toolbox	900
Symbolic Math Toolbox	600
Extended Symbolic Math Toolbox [8]	900
Partial Differential Equation Toolbox	900
Genetic Algorithm and Direct Search Toolbox [21]	700
Statistics and Data Analysis	
Statistics Toolbox	800
Neural Network Toolbox	900
Curve Fitting Toolbox	500
Spline Toolbox	400
Model-Based Calibration Toolbox [2, 9, 14, 16]	7,000
Bioinformatics Toolbox [18]	1,000
Control System Design and Analysis	
Control System Toolbox	1,000
System Identification Toolbox [10]	900
Fuzzy Logic Toolbox	900
Robust Control Toolbox [12]	1,800
Model Predictive Control Toolbox [13]	900
Signal Processing and Communications	
Signal Processing Toolbox	800
Communications Toolbox [5]	1,000
Filter Design Toolbox [5, 22]	1,000
Filter Design HDL Coder [5, 6, 17]	2,000
Wavelet Toolbox [10, 11]	900
Fixed-Point Toolbox	1,000
RF Toolbox	1,000
Link for Code Composer Studio™ [2, 5]	1,000
Link for ModelSim® [3, 19]	2,000

	Individual
Image Processing	
Image Processing Toolbox [10]	900
Image Acquisition Toolbox [2, 11]	900
Mapping Toolbox	900
Test & Measurement	
Data Acquisition Toolbox [2]	900
Instrument Control Toolbox [3]	700
Image Acquisition Toolbox [2, 11]	900
OPC Toolbox [2]	1,000
Financial Modeling and Analysis	
Financial Toolbox [9]	900
Financial Derivatives Toolbox [7]	1,000
GARCH Toolbox [9]	1,000
Financial Time Series Toolbox [7]	600
Datafeed Toolbox [2]	1,000
Fixed-Income Toolbox [7]	1,000
Application Deployment	
MATLAB Compiler [20]	5,000
Excel Link [2]	200
MATLAB Web Server [4]	2,000
Application Deployment Targets	
MATLAB Builder for COM [2, 15]	3,000
MATLAB Builder for Excel [2, 15]	4,000
Database Connectivity and Reporting	
Database Toolbox	1,000
MATLAB Report Generator	500

Notes

1: Prerequisite for all other products
2: Available only for Windows®
3: Available only for Windows, Solaris®, or Linux
4: Available only for Windows NT, Solaris, or Linux
5: Requires Signal Processing Toolbox
6: Requires Filter Design Toolbox
7: Requires Financial Toolbox
8: Includes Symbolic Math Toolbox functionality
9: Requires Statistics and Optimization toolboxes
10: Signal Processing Toolbox recommended
11: Image Processing Toolbox recommended
12: Requires Control System Toolbox
13: Control System Toolbox recommended
14: Requires Simulink®
15: Requires MATLAB Compiler
16: Requires Extended Symbolic Math Toolbox
17: Requires Fixed-Point Toolbox
18: Requires Statistics Toolbox
19: Requires Simulink and Simulink Fixed Point for use with Simulink features
20: Available only for Windows or Linux
21: Requires Optimization Toolbox
22: Requires Fixed-Point Toolbox to create fixed point filters
23: Requires access to MATLAB Distributed Computing Engine
24: Available only for Windows, Solaris, Linux (32 & 64 bit), and Mac
25: Requires access to Distributed Computing Toolbox
26. MATLAB not required to run

Prices are per unit, listed in U.S. dollars, valid for program installation and use in the U.S. or Canada only, and are subject to change without notice.

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Simulink Report Generator [7]	500
Fixed Point Modeling	
Simulink Fixed Point [8]	1,000
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SimDriveline	3,000
SimPowerSystems	3,000
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Virtual Reality Toolbox [16]	1,000
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Notes

1: Requires MATLAB
2: Available only for Windows
3: Prerequisite for all products on this page
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6: Requires Stateflow
7: Requires MATLAB Report Generator
8: Requires Fixed-Point Toolbox
9: Requires Control System Toolbox
10: Available only for Windows, Solaris, or Linux
11: Requires xPC Target
12: Requires Signal Processing Blockset
13: Requires Communications Toolbox
14: Requires Link for Code Composer Studio. Simulink Fixed Point recommended
15: Requires Communications Blockset
16: Requires Simulink for blockset portion of product
17: Requires RF Toolbox
18: Requires Real-Time Workshop Embedded Coder
19: Requires Link for Code Composer Studio and Simulink Fixed Point
20: Requires Simulink and Simulink Fixed Point for use with Simulink features
21: Requires Optimization Toolbox
22: Real-Time Workshop Embedded Coder recommended
23: Optimization Toolbox recommended
24: Genetic Algorithm and Direct Search Toolbox recommended
25: Requires Simulink Fixed Point for generating fixed point code
26: Requires Simulink Fixed Point for simulation of fixed point data types
27: Requires Image Processing Toolbox

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Optimization Toolbox 3

Solve standard and large-scale optimization problems

The Optimization Toolbox extends the MATLAB® technical computing environment with tools and widely used algorithms for standard and large-scale optimization. These algorithms solve constrained and unconstrained continuous and discrete problems. The toolbox includes functions for linear programming, quadratic programming, nonlinear optimization, nonlinear least squares, nonlinear equations, multi-objective optimization, and binary integer programming.

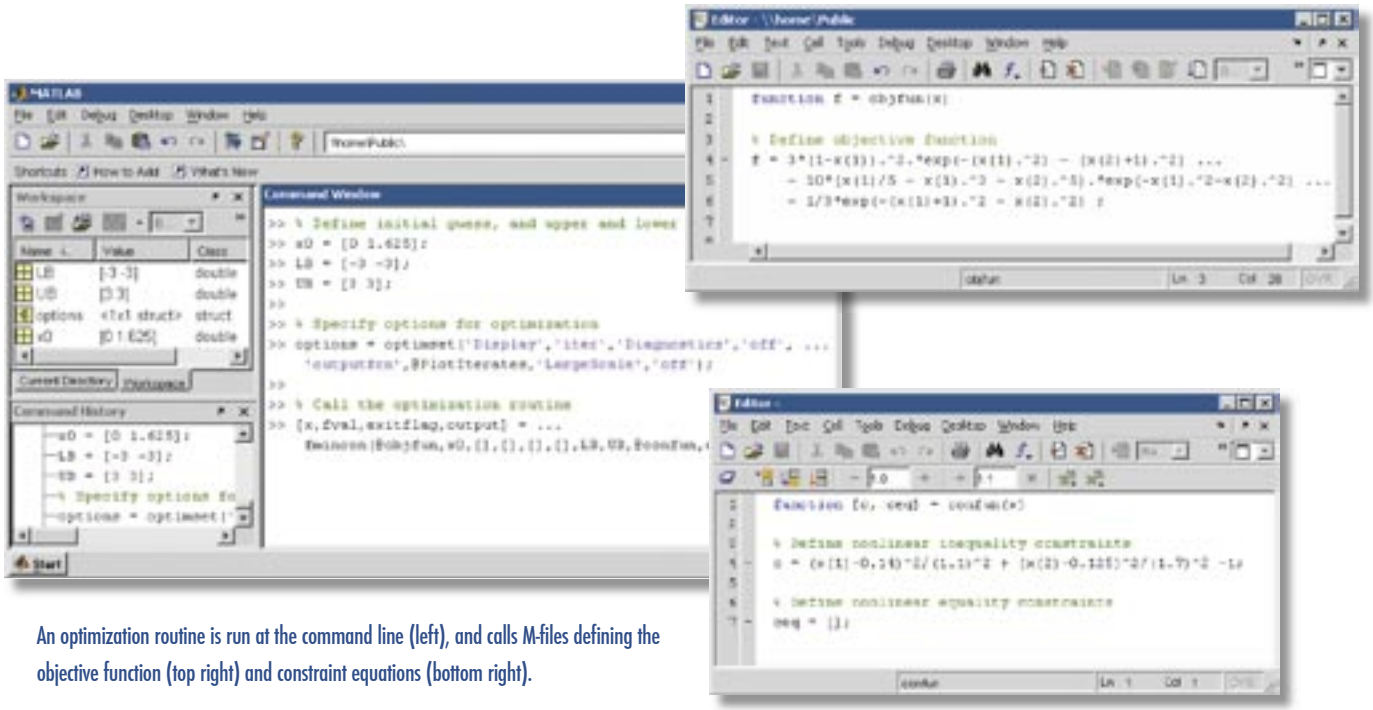
MATLAB and the Optimization Toolbox let you easily define models, gather data, manage model formulations, and analyze results. They give engineers and scientists the tools needed to find optimal solutions, perform tradeoff analysis, balance multiple design alternatives, and quickly incorporate optimization methods in their algorithms and models.

Toolbox functions, which can be accessed via the MATLAB command line, are written in the open MATLAB language. This means that you can inspect the algorithms, modify the source code, and create your own custom functions.

KEY FEATURES

- Tools for defining, solving, and assessing optimization problems
- Solvers for nonlinear optimization and multi-objective optimization
- Solvers for nonlinear least-squares, data fitting, and nonlinear equations
- Methods for solving quadratic and linear programming problems
- Methods for solving binary integer programming problems

A blurred image is recovered using the large-scale linear least squares algorithm in the Optimization Toolbox.



An optimization routine is run at the command line (left), and calls M-files defining the objective function (top right) and constraint equations (bottom right).

Defining, Solving, and Assessing Optimization Problems

The Optimization Toolbox includes the most widely used methods for performing minimization and maximization. The toolbox implements both standard and large-scale algorithms, enabling you to solve problems by exploiting their sparsity or structure. The command-line interface gives you access to tools to define, run, and assess your optimization.

You can further manipulate and diagnose your optimization using the diagnostic outputs from the optimization methods. Using an output function, you can also write results to files, create your own stopping criteria, and write your own graphical user interfaces to run the toolbox solvers.

Nonlinear Optimization and Multi-Objective Optimization

Unconstrained Nonlinear Optimization

The Optimization Toolbox uses three methods to solve unconstrained nonlinear minimization problems: quasi-Newton, Nelder-Mead, and trust-region.

The **Quasi-Newton** method uses a mixed quadratic and cubic line search procedure and the BFGS formula for updating the approximation of the Hessian matrix.

Nelder-Mead is a direct-search method that uses only function values (does not require derivatives) and handles non-smooth objective functions.

Trust-region is used for large-scale problems where sparsity or structure can be exploited.

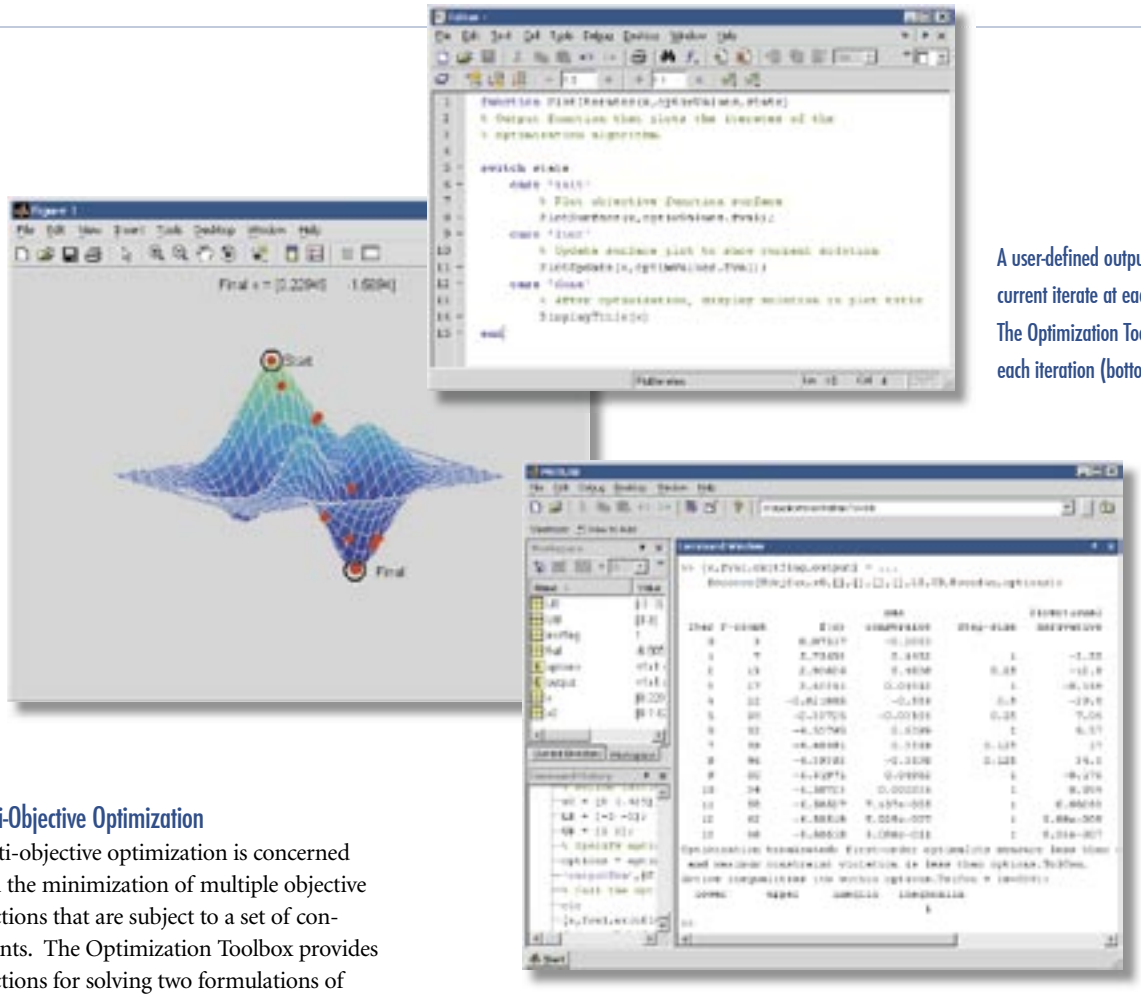
The trust region method, which is based on an interior-reflective Newton method, enables you to calculate Hessian-times-vector products in a function without having to form the Hessian matrix explicitly. You can also adjust the bandwidth of the preconditioner used in the Newton iteration.

Constrained Nonlinear Optimization

Constrained nonlinear optimization problems are composed of nonlinear objective functions and may be subject to linear and nonlinear constraints. The Optimization Toolbox uses two methods to solve these problems: trust-region and active set sequential quadratic programming.

Trust-region is used for bound constrained problems or linear equalities only.

Active set sequential quadratic programming is used for general nonlinear optimization.



A user-defined output function (top) plots the current iterate at each algorithm iteration (left). The Optimization Toolbox also provides details for each iteration (bottom).

Multi-Objective Optimization

Multi-objective optimization is concerned with the minimization of multiple objective functions that are subject to a set of constraints. The Optimization Toolbox provides functions for solving two formulations of multi-objective optimization problems: goal attainment and minimax.

The **goal attainment** problem involves reducing the value of a linear or nonlinear vector function to attain the goal values given in a goal vector. The relative importance of the goals is indicated using a weight vector. The goal attainment problem may also be subject to linear and nonlinear constraints.

The **minimax** problem involves minimizing the worst-case value of a set of multivariate functions, possibly subject to linear and nonlinear constraints.

The Optimization Toolbox transforms both types of multi-objective problems into standard constrained optimization problems and then solves them using a sequential quadratic programming approach.

Nonlinear Least Squares, Data Fitting, and Nonlinear Equations

The Optimization Toolbox can solve nonlinear least squares problems, data fitting problems, and systems of nonlinear equations.

The toolbox uses three methods for solving nonlinear least squares problems: trust-region, Levenberg-Marquardt, and Gauss-Newton.

Trust-region is used for unconstrained and bound constrained problems.

Levenberg-Marquardt is a line search method whose search direction is a cross between the Gauss-Newton and steepest descent directions.

Gauss-Newton is a line search method that chooses a search direction based on the solution to a linear least squares problem.

The toolbox also includes a specialized interface for data-fitting problems to find the member of a family of nonlinear functions that best fits a set of data points. The toolbox uses the same methods for data-fitting problems as it uses for nonlinear least-squares problems.

The Optimization Toolbox implements a dogleg trust region method for solving a system of nonlinear equations where there are as many equations as unknowns. The toolbox can also solve this problem using either the trust-region, the Levenberg-Marquandt, or the Gauss-Newton method.

Quadratic and Linear Programming

Quadratic Programming

Quadratic programming problems involve minimizing a multivariate quadratic function subject to linear equality and inequality constraints. The toolbox implements three methods for solving these problems: trust-region, preconditioned conjugate gradient, and active set.

Trust-region is used for bound constrained problems.

Preconditioned conjugate gradient is used for problems subject to equality constraints.

Active set minimizes the objective at each iteration over the active set (a subset of the constraints that are locally active) until it reaches a solution.

Linear Programming

Linear programming problems consist of a linear expression for the objective function and linear equality and inequality constraints. Two methods are used to solve this type of problem: simplex and interior point.

The interior point method is based on a primal-dual predictor-corrector algorithm, and is used for large-scale linear problems.

The simplex method is a systematic procedure for generating and testing candidate vertex solutions to a linear program.

Binary Integer Programming

Binary integer programming problems involve minimizing a linear objective function subject to linear equality and inequality constraints. Each variable in the optimal solution must be either a 0 or a 1.

The Optimization Toolbox solves these problems using a branch-and-bound algorithm that:

- Searches for a feasible binary integer solution
- Updates the best binary point found as the search tree grows
- Verifies that no better solution is possible by solving a series of linear programming relaxation problems

Required Products

MATLAB

Related Products

Curve Fitting Toolbox. Perform model fitting and analysis

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Signal Processing Toolbox 6

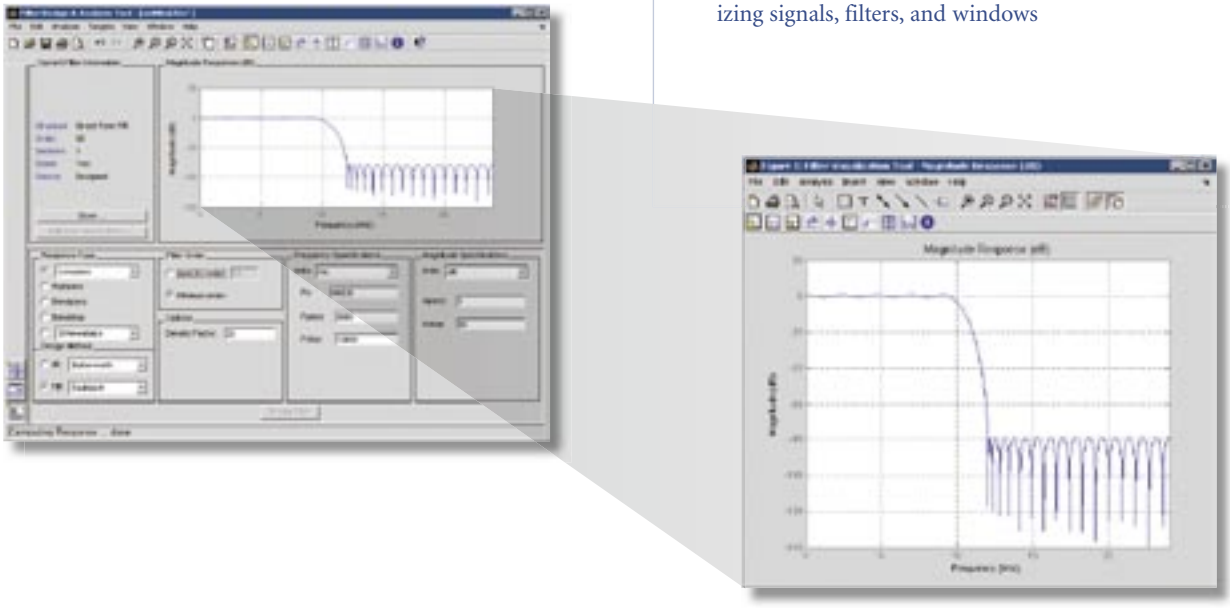
Perform signal processing, analysis, and algorithm development

The Signal Processing Toolbox is a collection of industry-standard algorithms for analog and digital signal processing. It provides graphical user interfaces (GUIs) for interactive design and analysis and command-line functions for advanced algorithm development.

Most toolbox functions are implemented in the open MATLAB® language. This means that you can inspect the algorithms, modify the source code, and create your own custom functions. You can use the toolbox for applications such as speech and audio processing, wired and wireless communications, financial modeling and analysis, and medical imaging and instrumentation.

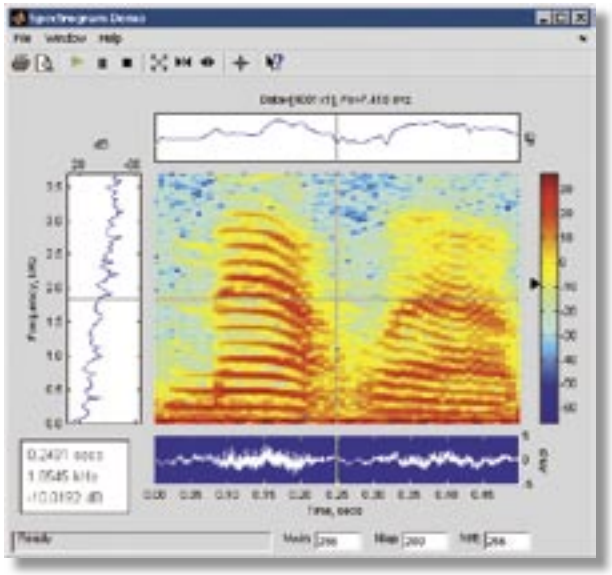
KEY FEATURES

- Comprehensive set of signal and linear system models
- Tools for finite impulse response (FIR) and infinite impulse response (IIR) digital filter design, analysis, and implementation
- Tools for analog filter design
- Access to the most widely used transforms, such as fast Fourier and discrete cosine
- Tools for spectral analysis and statistical signal processing
- Functions for parametric time-series modeling
- Routines for waveform generation, including a Gaussian pulse generator, a periodic sinc generator, and a pulse train generator
- Extensive data windowing algorithms
- Graphical user interfaces for designing, analyzing, and visualizing signals, filters, and windows



The magnitude response of a lowpass filter, designed in the Filter Design and Analysis Tool (left), and a print preview of the filter's response (above), created in the Filter Visualization Tool.

A spectrogram of the input signal showing the signal's time-frequency distribution and power spectral density, created using the Signal Processing Toolbox spectrogram demo.



Signal and Linear System Models

The Signal Processing Toolbox provides a broad range of models for representing signals and linear time-invariant systems, including representations for transfer functions, state space, and zero-pole gain. The toolbox also includes functions for transforming models from one representation to another.

Digital Filter Design Methods

A full suite of design methods is available for finite impulse response (FIR) and infinite impulse response (IIR) digital filters. These methods support the rapid design and evaluation of lowpass, highpass, bandpass, bandstop, and multiband filters, such as Butterworth, Chebyshev, elliptic, Yule-Walker, window-based, least squares, and Parks-McClellan (real and complex). Available filter structures include the direct forms I and II, lattice, lattice-ladder, and second-order sections.

Transforms

The Signal Processing toolbox provides tools for computing the most widely used transforms. These include discrete Fourier, discrete cosine, Hilbert, and Goertzel.

Spectral Analysis Tools

The Signal Processing Toolbox provides capabilities for frequency-domain analysis and spectral estimation, including tools for measuring power spectral density, mean-square spectrum, and average power. Several of these methods are based on a highly optimized fast Fourier transform. The spectral analysis methods include Welch, Burg, modified covariance, Yule-Walker, the multitaper method, and the MUSIC method.

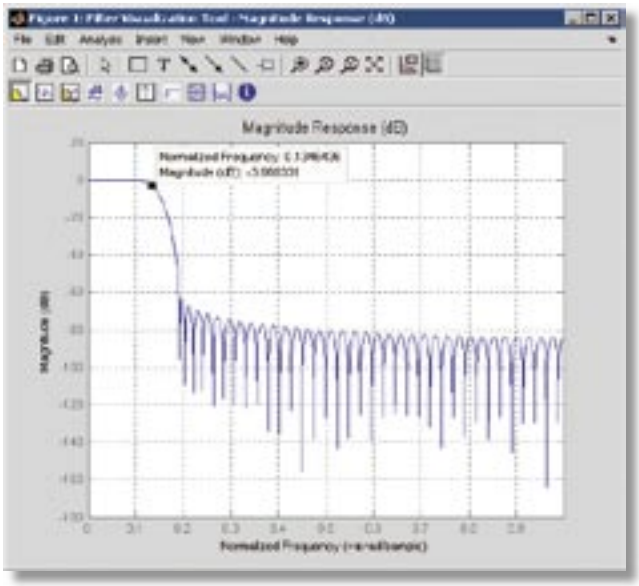
GUIs for Filter Design, Analysis, and Visualization

The GUIs in the Signal Processing Toolbox let you interactively view and measure signals, design and apply filters, design and analyze spectral windows, and perform spectral analysis while exploring the effects of different parameters and methods. The GUIs are particularly useful for visualizing time-frequency information, spectra, and pole-zero locations. For example, you can interactively design a filter by graphically placing the poles and zeros in the z-plane.

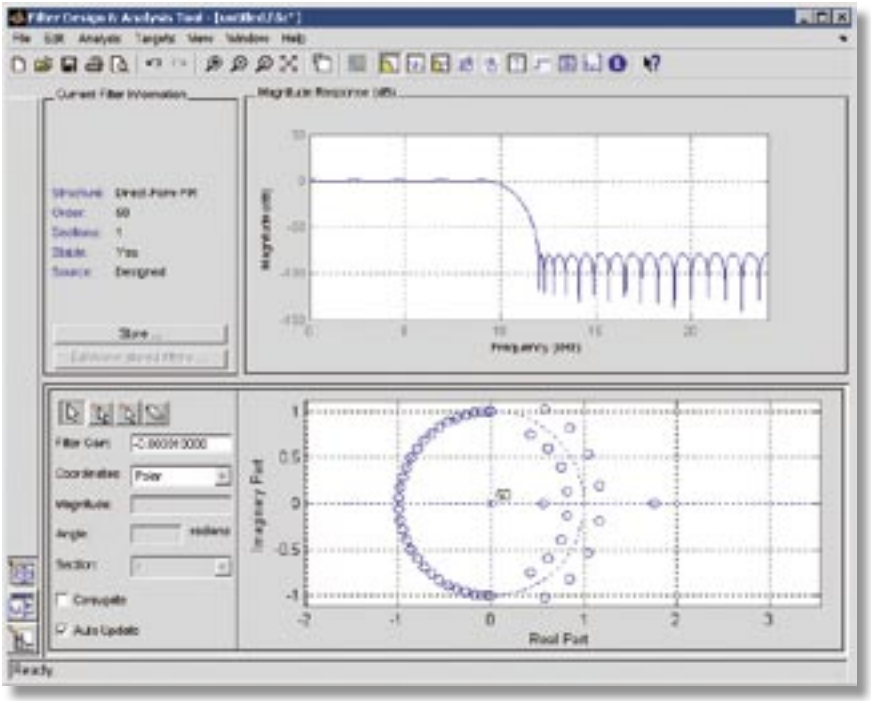
The Signal Processing Toolbox provides four GUIs: FDATool, FVTool, SPTool, and WINTool.

FDATool provides access to most FIR and IIR filter design methods in the toolbox. Additionally, you can:

- Design filters by graphically placing poles and zeros in the z-plane
- Analyze filters by examining magnitude, phase, impulse, and step responses, group delay, and pole-zero plots
- Generate C header files
- Import designed filters and filter coefficients stored in the MATLAB workspace and export filter coefficients
- Access additional filter design methods and quantization features in the Filter Design Toolbox (available separately)



Magnitude response of the specified digital filter, created using FVTool. Data markers determine the frequency and magnitude values of any chosen data point.

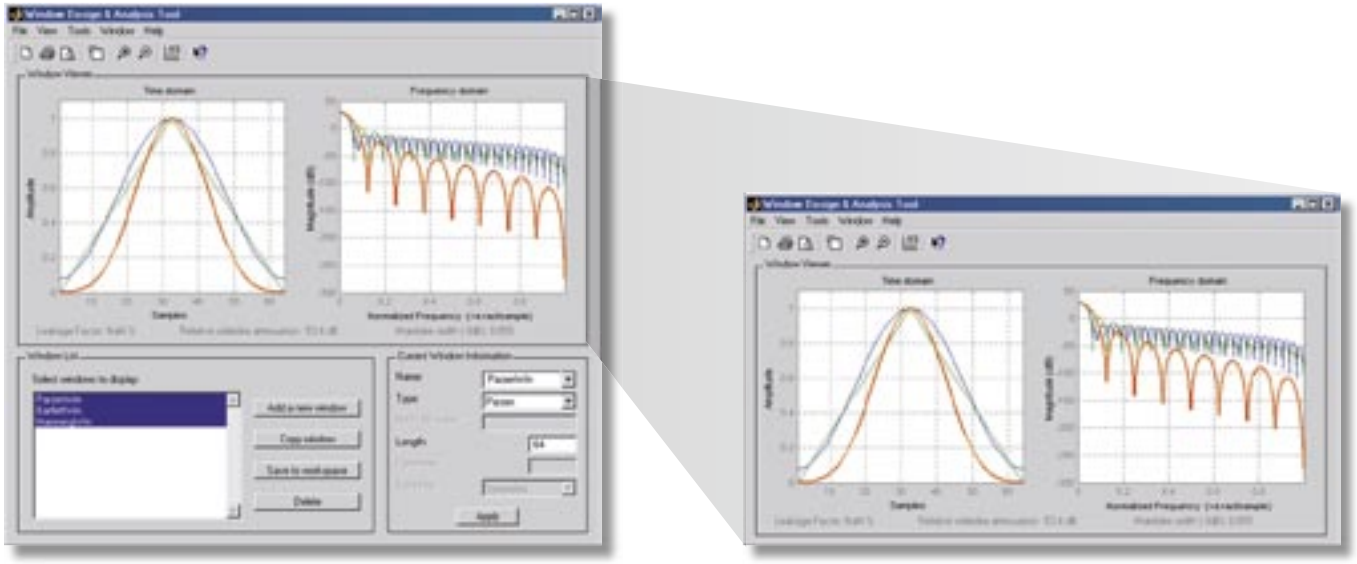


FDATool includes a Pole/Zero Editor that lets you design a filter through the graphical placement of poles and zeros.

FVTool lets you view the characteristics of a designed or imported filter, including its magnitude response, phase response, group delay, pole-zero plot, impulse response, and step response.

SPTool provides access to signal, filter, and spectral analysis functions. You can:

- Measure and analyze the time-domain information of one or more signals and send audio signal to the PC's sound card
- Apply the filter to a selected signal
- Graphically analyze frequency-domain data using a variety of spectral estimation methods, including Burg, FFT, multitaper (MTM), MUSIC, eigenvector, Welch, and Yule-Walker AR



The Window Viewer in WINTool displays the time-domain and frequency-domain representations of multiple windows for easy comparison.

WINTool lets you design and analyze spectral windows. You can:

- Display time-domain and frequency-domain representations of the selected window(s)
- Export window vectors or window objects to the MATLAB workspace, a MAT-file, or a text file
- View typical window measurements, such as leakage factor, relative sidelobe attenuation, and mainlobe width
- Visualize, annotate, and print time-domain and frequency-domain plots

Required Products

MATLAB

Related Products

Communications Toolbox. Design and analyze algorithms for the physical layer of communication systems

Filter Design Toolbox. Design and analyze fixed-point, adaptive, and multirate filters

Image Processing Toolbox. Perform image processing, analysis, and algorithm development

Signal Processing Blockset. Design and simulate signal processing systems and devices

Wavelet Toolbox. Analyze and synthesize signals and images using wavelet techniques

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Statistics Toolbox 5

Apply statistical algorithms and probability models

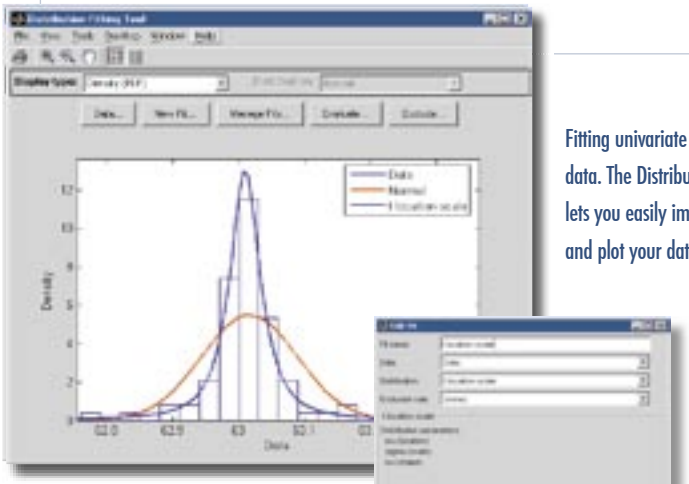
The Statistics Toolbox provides engineers, scientists, researchers, financial analysts, and statisticians with a comprehensive set of tools to assess and understand their data. It includes functions and interactive tools for analyzing historical data, modeling data, simulating systems, developing statistical algorithms, and learning and teaching statistics.

The toolbox supports a wide range of tasks, from basic descriptive statistics to developing and visualizing multidimensional nonlinear models. It offers a rich set of statistical plot types and interactive graphics, such as polynomial fitting and response surface modeling.

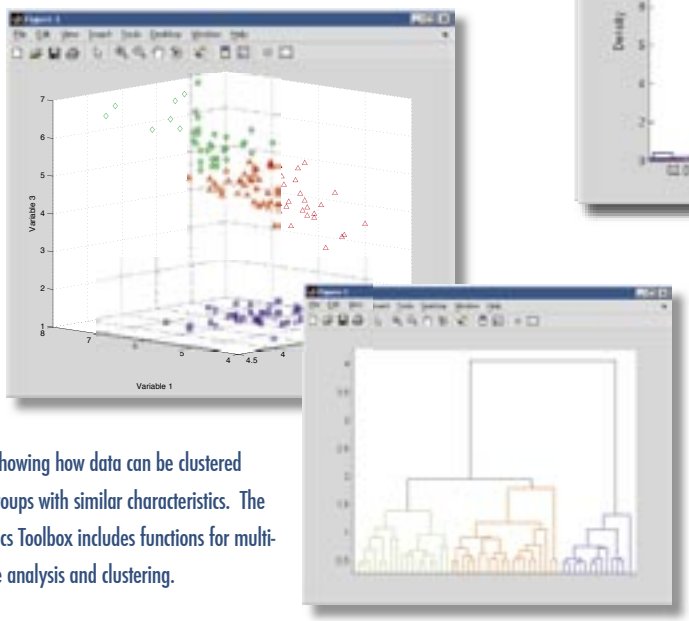
All toolbox functions are written in the open MATLAB® language. This means that you can inspect the algorithms, modify the source code, and create your own custom functions.

KEY FEATURES

- Calculation and fitting of probability distributions
- Linear and nonlinear modeling
- Multivariate statistics
- Descriptive statistics
- Analysis of variance (ANOVA)
- Hypothesis testing
- Industrial statistics (Statistical Process Control, Design of Experiments)
- Statistical plotting and data visualization



Fitting univariate distributions to data. The Distribution Fitting Tool lets you easily import, analyze, and plot your data.



Plots showing how data can be clustered into groups with similar characteristics. The Statistics Toolbox includes functions for multivariate analysis and clustering.

Probability Distributions

The Statistics Toolbox includes interactive graphical user interfaces (GUIs) and command-line tools that make it easy to look at probability distributions, fit them to your data, or generate random samples from them.

Graphical User Interfaces

The Distribution Fitting Tool is a GUI that enables you to learn about a variety of probability distributions—for example, you can graph a probability density function or cumulative distribution function and investigate how a distribution's parameters affect its position and shape.

The Distribution Fitting Tool lets you fit data using 16 predefined probability distributions, a nonparametric (kernel smoothing) estimator, or a custom distribution that you define yourself. It supports both complete and censored (reliability) data and lets you exclude data, save and load sessions, and generate M-code.

A second GUI provides a random number generator to simulate behavior associated with particular distributions. You can use this random data to test hypotheses or models under different conditions.

Command-line Functions

From the command line, you can perform the following additional tasks:

- Calculate the probability density function (pdf)
- Calculate the cumulative distribution function (cdf) and its inverse
- Compute mean and variance
- Generate random numbers (such as noise simulation)
- Estimate parameters

The Statistics Toolbox also includes functions for generating random samples from multivariate distributions, such as t, normal, and Wishart; sampling from finite populations; and performing Latin hypercube sampling.

Linear and Nonlinear Modeling

The linear and nonlinear models provided in the Statistics Toolbox let you model a response variable as a function of one or more predictor variables. These models make predictions, establish relationships between variables, or simplify a problem. For example, linear and nonlinear regression models help establish which variables have the most impact on a response. Robust regression methods can help you find outliers and reduce their effect on the fitted model.

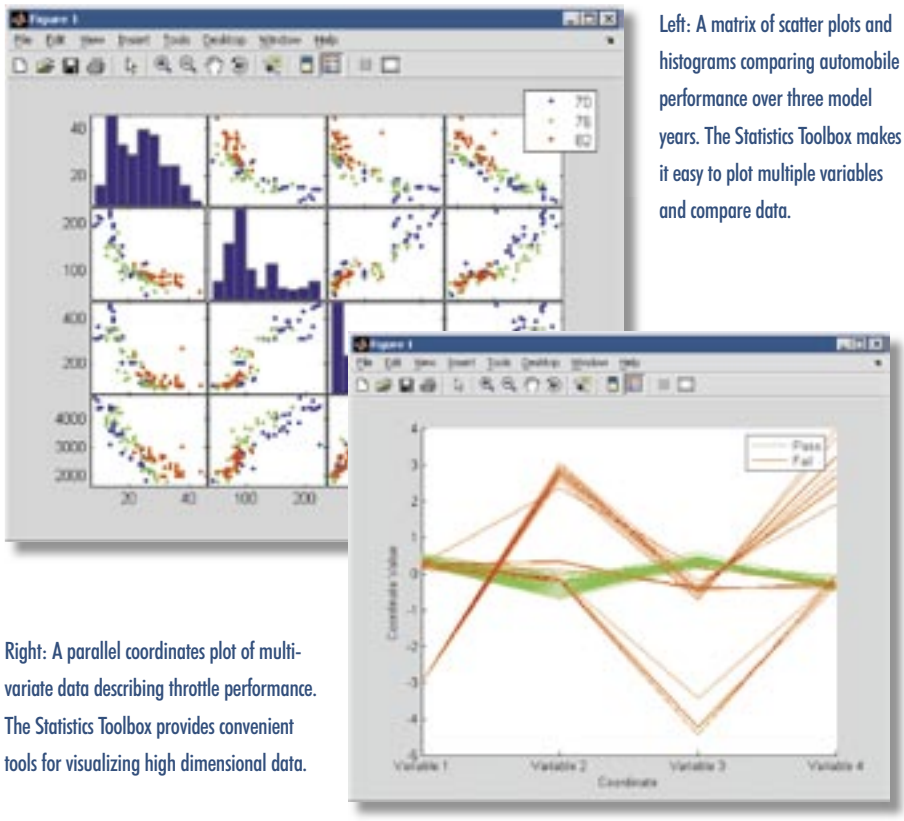
The toolbox provides linear algorithms for:

- One-way, two-way, and multiway ANOVA
- Mixed random and fixed-effects ANOVA
- Polynomial, stepwise, ridge, robust, and multiple linear regression
- Generalized linear models
- Response surface fitting

The toolbox provides nonlinear fitting functions for classification and regression trees and for nonlinear least squares. Using nonlinear least square functions, you can:

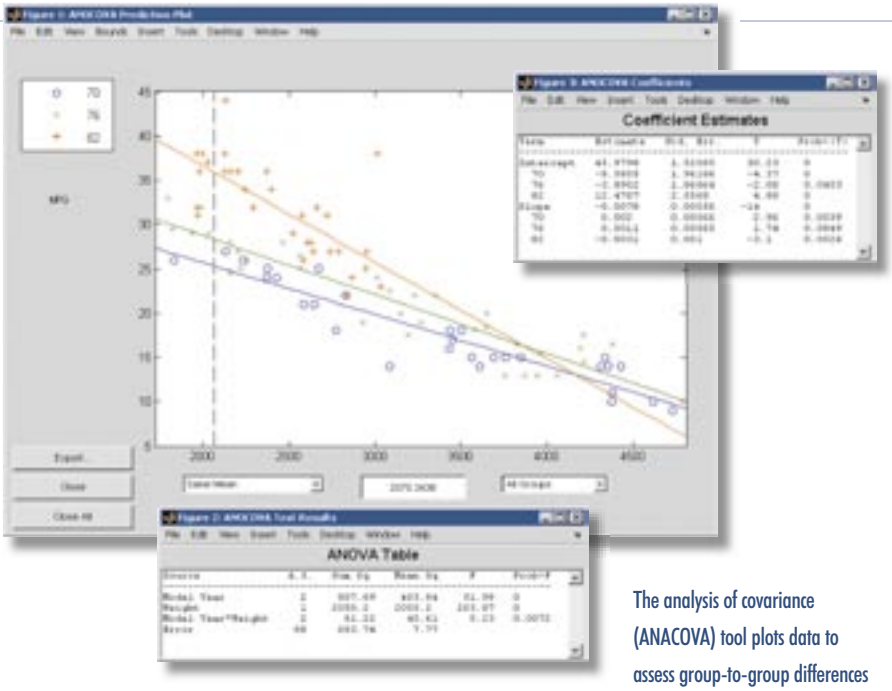
- Estimate parameters
- Interactively visualize and predict multidimensional nonlinear fitting
- Set confidence intervals for parameters and predicted values

You can also use the toolbox to work with Hidden Markov models. You can estimate the parameters of a model using the Baum-Welch algorithm, calculate the most likely path through a model using the Viterbi algorithm, and generate random sequences from a given model.



Left: A matrix of scatter plots and histograms comparing automobile performance over three model years. The Statistics Toolbox makes it easy to plot multiple variables and compare data.

Right: A parallel coordinates plot of multivariate data describing throttle performance. The Statistics Toolbox provides convenient tools for visualizing high dimensional data.



The analysis of covariance (ANACOVA) tool plots data to assess group-to-group differences and the impact of a predictor variable on a response variable.

Multivariate Statistics

Multivariate statistics methods let you analyze your data by evaluating groups of variables together. You can:

- Segment data in clusters for further analysis
- Visualize and assess the group-to-group differences in a data set
- Reduce a large set of variables to a more manageable but still representative set

Multivariate statistics tasks supported by the Statistics Toolbox include:

- Factor analysis
- Principal components analysis (PCA)
- Factor rotation
- Cluster analysis (both hierarchical and k-means)
- Discriminate analysis
- Multivariate ANOVA
- Multidimensional scaling (classical, metric, and nonmetric)
- Multivariate plotting

Descriptive Statistics

Descriptive statistics methods enable you to quickly understand and describe potentially large sets of data. The Statistics Toolbox includes functions for calculating:

- Measures of central tendency (measures of location), including average, median, and various means
- Measures of dispersion (measures of spread), including range, variance, standard deviation, and mean absolute deviation
- Linear and rank correlation
- Results based on data with missing values
- Percentile and quartile estimates
- Bootstrap statistics
- Density estimates (using a kernel smoothing function)

These functions help you summarize the values in a data sample with a few highly relevant numbers.

Analysis of Variance

Analysis of variance (ANOVA) lets you determine whether data sets from different groups have different characteristics. You can classify groups using discrete predictor variables. A follow-up multiple comparisons analysis can pinpoint which pairs of groups differ from each other.

The Statistics Toolbox includes algorithms for ANOVA and related techniques, including:

- One-way ANOVA with graphics
- Two-way ANOVA for balanced data
- Multiway ANOVA for unbalanced data, (both fixed and random effects)
- Analysis of covariance
- One-way multivariate ANOVA
- Nonparametric one- and two-way ANOVA (Kruskal-Wallis, Friedman)
- Multiple comparison of group means, slopes, and intercepts

Hypothesis Testing

Random variation often makes it difficult to determine whether samples taken under different conditions really are different. Hypothesis testing is an effective tool for analyzing whether sample-to-sample differences are significant and require further evaluation or are consistent with random and expected data variation.

The Statistics Toolbox supports the most widely used parametric and nonparametric hypothesis testing procedures, such as:

- One- and two-sample t tests
- One-sample z test
- Nonparametric tests for one sample
- Nonparametric tests for two independent samples
- Distribution tests (Jarque-Bera, Lilliefors, and Kolmogorov-Smirnov)
- Comparison of distributions (two-sample Kolmogorov-Smirnov)

Industrial Statistics

The Statistics Toolbox provides a set of functions that support statistical process control (SPC). These functions enable you to monitor and improve products or processes by evaluating process variability. Design-of- Experiments (DOE) functions help you create and test practical plans for gathering data for statistical modeling. These plans show you how to manipulate your data inputs in tandem to generate information about their effect on the outputs.

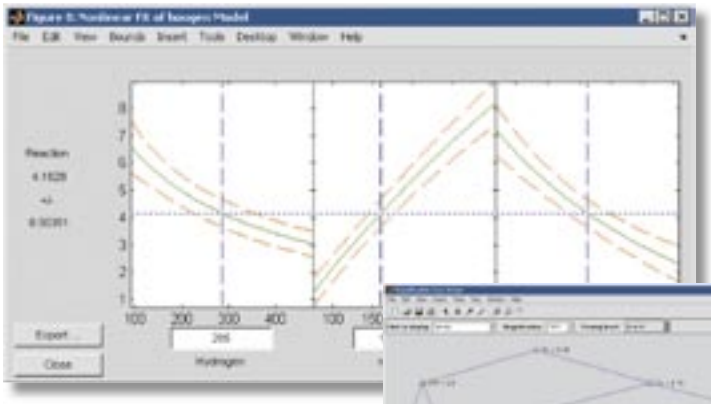
The Statistics Toolbox supports two areas of industrial statistics:

- Control charts and capabilities studies for SPC
- D-optimal, factorial, Hadamard (Plackett-Burman), central composite, and Box-Behnken designs used in conjunction with DOE

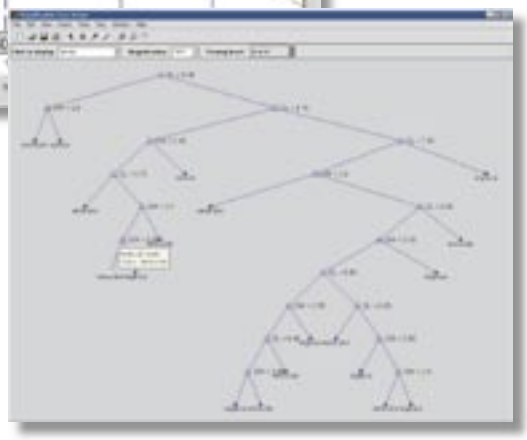
Statistical Plotting and Interactive Graphics

The Statistics Toolbox includes numerous functions that help you represent your data graphically. In addition to the standard set of MATLAB plot types, the Statistics Toolbox includes box plots, probability plots, histograms and 3-D histograms, control charts, quantile-quantile plots, and several multivariate plots. It also provides interactive graphics that enhance analysis in areas such as:

- Nonlinear and polynomial fitting and prediction
- Exploration of distribution functions and distribution fitting and analysis
- Interactive random number generation
- Response surface modeling
- Interactive process experimentation and analysis
- Stepwise regression analysis



Left: A model of a chemical reaction of an experiment using the Design-of-Experiments and surface fitting capabilities of the Statistics Toolbox.



Right: Fitting a decision tree to data. The fitting capabilities in the Statistics Toolbox let you visualize a decision tree by drawing a diagram of the decision rule and group assignments.

Required Products

MATLAB

Related Products

Bioinformatics Toolbox. Read, analyze, and visualize genomic, proteomic, and microarray data

Curve Fitting Toolbox. Perform model fitting and analysis

Financial Toolbox. Analyze financial data and develop financial algorithms

Optimization Toolbox. Solve standard and large-scale optimization problems

Signal Processing Toolbox. Perform signal processing, analysis, and algorithm development

For information on related products, visit *www.mathworks.com/products/statistics*

Platform and System Requirements

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SCHOTT
TOTAL CUSTOMER CARE

BG 39

Reflection factor	
P_d	0.91
Bubble content	
Bubble class	2
Chemical resistance	
FR class	0
SR class	5.1
AR class	3.0

Density	
ρ [g/cm^3]	2.73
Transformation temperature	
Tg [°C]	321
Thermal expansion	
$\alpha_{-30/+70°C}$ [10^{-6}/K]	11.6
$\alpha_{20/200°C}$ [10^{-6}/K]	13.1
Temperature coefficient	
T_k [nm/°C]	

Per DIN 58191 **BP 475/269**
Per DIN 58191 **KP 609**

Ionically colored glass

Limit values of τ_i
for thickness d = 1 mm

Wave-length [nm]	Limits	Value from catalog curve
350	≥0.60	0.65
405	≥0.85	0.88
514	≥0.93	0.97
633	≤0.30	0.26
694	≤0.03	0.02
1060	≤0.001	$1 \cdot 10^{-4}$

Refractive index n

λ [nm]	Element	n
404.7	Hg	1.55
587.6	He	1.54

Tristimulus values

	d [mm]	x	y	Y	λ_d [nm]	P_e
A	1	0.365	0.434	66	500	0.19
2856	2	0.314	0.444	53	500	0.30
K	3	0.279	0.449	45	499	0.39
	5	0.235	0.450	35	498	0.49
	1	0.344	0.418	67	498	0.19
3200	2	0.296	0.425	55	498	0.31
K	3	0.264	0.426	47	497	0.39
	5	0.223	0.425	37	497	0.49
	1	0.257	0.326	73	491	0.21
D_{65}	2	0.226	0.321	62	490	0.32
	3	0.207	0.317	55	490	0.40
	5	0.183	0.311	45	490	0.49

Application notes
Band pass filter
- see section 6.7.3

Short pass filter
- see section 6.7.2

[!!]
Long-term changes in the polished surface are possible
- see section 5.5

Status June 1997

Transmittance τ and internal transmittance τ_i at d = 1 mm

λ [nm]	τ	τ_i	λ [nm]	τ	τ_i
200	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	700	0.009	0.01
210	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	710	0.005	0.005
220	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	720	0.003	0.003
230	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	730	$9 \cdot 10^{-4}$	0.001
240	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	740	$6 \cdot 10^{-4}$	$7 \cdot 10^{-4}$
250	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	750	$3 \cdot 10^{-4}$	$3 \cdot 10^{-4}$
260	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	760	$9 \cdot 10^{-5}$	$1 \cdot 10^{-4}$
270	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	770	$8 \cdot 10^{-5}$	$9 \cdot 10^{-5}$
280	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	780	$5 \cdot 10^{-5}$	$5 \cdot 10^{-5}$
290	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	790	$3 \cdot 10^{-5}$	$3 \cdot 10^{-5}$
300	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	800	$2 \cdot 10^{-5}$	$2 \cdot 10^{-5}$
310	$9 \cdot 10^{-5}$	$1 \cdot 10^{-4}$	850	$<1 \cdot 10^{-5}$	$1 \cdot 10^{-5}$
320	0.04	0.04	900	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$
330	0.23	0.26	950	$<1 \cdot 10^{-5}$	$1 \cdot 10^{-5}$
340	0.45	0.49	1000	$3 \cdot 10^{-5}$	$3 \cdot 10^{-5}$
350	0.59	0.65	1060	$9 \cdot 10^{-5}$	$1 \cdot 10^{-4}$
360	0.67	0.73	1100	$4 \cdot 10^{-4}$	$4 \cdot 10^{-4}$
370	0.71	0.78	1200	0.003	0.003
380	0.74	0.82	1300	0.02	0.02
390	0.77	0.85	1400	0.06	0.07
400	0.79	0.87	1500	0.16	0.18
410	0.81	0.89	1600	0.31	0.34
420	0.82	0.90	1700	0.46	0.51
430	0.83	0.92	1800	0.67	0.74
440	0.85	0.93	1900	0.67	0.74
450	0.85	0.94	2000	0.74	0.81
460	0.86	0.95	2100	0.78	0.86
470	0.87	0.96	2200	0.79	0.87
480	0.88	0.96	2300	0.78	0.86
490	0.88	0.97	2400	0.78	0.86
500	0.88	0.97	2500	0.75	0.82
510	0.88	0.97	2600	0.67	0.74
520	0.88	0.97	2700	0.63	0.69
530	0.87	0.96	2800	0.30	0.33
540	0.86	0.94	2900	0.06	0.07
550	0.83	0.91	3000	0.02	0.02
560	0.80	0.87	3200	0.002	0.002
570	0.75	0.82	3400	$3 \cdot 10^{-4}$	$3 \cdot 10^{-4}$
580	0.68	0.75	3600	$6 \cdot 10^{-4}$	$6 \cdot 10^{-4}$
590	0.61	0.67	3800	0.002	0.002
600	0.52	0.58	4000	$6 \cdot 10^{-4}$	$7 \cdot 10^{-4}$
610	0.43	0.48	4200	$2 \cdot 10^{-5}$	$2 \cdot 10^{-5}$
620	0.34	0.38	4400	$3 \cdot 10^{-4}$	$3 \cdot 10^{-4}$
630	0.26	0.29	4600	$6 \cdot 10^{-4}$	$7 \cdot 10^{-4}$
640	0.19	0.21	4800	0.003	0.003
650	0.13	0.14	5000	0.003	0.003
660	0.08	0.09	5200	0.003	0.003
670	0.05	0.06			
680	0.03	0.03			
690	0.02	0.02			

SCHOTT
TOTAL CUSTOMER CARE

GG 475

Reflection factor	
P_d	0.91
Bubble content	
Bubble class	3
Chemical resistance	
FR class	3
SR class	4.4
AR class	1.0

Density	
ρ [g/cm^3]	2.75
Transformation temperature	
Tg [°C]	594
Thermal expansion	
$\alpha_{-30/+70°C}$ [10^{-6}/K]	9.8
$\alpha_{20/300°C}$ [10^{-6}/K]	10.6
Temperature coefficient	
T_k [nm/°C]	0.09

Per DIN 58191 **LP 475**
Per DIN 58191

Colloidally colored glass

Tolerances for long pass filters
for thickness d = 3 mm

λ_C (τ_i = 0,5 mm) [nm]	475±6
λ_S ($\tau_{iS} = 1 \cdot 10^{-5}$) [nm]	430
λ_p (τ_{ip} = 0.99)[nm]	530

Refractive index n

λ [nm]	Element	n
587.6	He	1.54
852.1	Cs	1.53
1014	Hg	1.53

Tristimulus values

	d [mm]	x	y	Y	λ_d [nm]	P_e
A	1	0,486	0.457	90	580	0.61
2856	2	0.490	0.461	90	580	0.67
K	3	0.493	0.464	90	580	0.70
	5	0.496	0.466	90	580	0.74
	1	0.469	0.463	90	578	0.62
3200	2	0.474	0.468	90	578	0.68
K	3	0.477	0.471	90	578	0.71
	5	0.481	0.474	90	578	0.75
	1	0.389	0.477	89	569	0.63
D_{65}	2	0.397	0.490	89	569	0.69
	3	0.403	0.498	88	569	0.72
	5	0.409	0.506	88	569	0.77

Application notes
Long pass filter
- see section 6.7.1

Status June 1997

Transmittance τ and internal transmittance τ_i at d = 3 mm

λ [nm]	τ	τ_i	λ [nm]	τ	τ_i
200	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	700	0.91	1.00
210	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	710	0.91	1.00
220	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	720	0.91	1.00
230	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	730	0.91	1.00
240	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	740	0.91	1.00
250	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	750	0.91	1.00
260	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	760	0.91	1.00
270	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	770	0.91	1.00
280	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	780	0.91	1.00
290	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	790	0.91	1.00
300	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	800	0.91	1.00
310	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	850	0.91	1.00
320	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	900	0.91	1.00
330	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	950	0.91	1.00
340	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	1000	0.91	1.00
350	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	1060	0.91	1.00
360	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	1100	0.91	1.00
370	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	1200	0.91	1.00
380	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	1300	0.91	1.00
390	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	1400	0.91	1.00
400	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	1500	0.91	1.00
410	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	1600	0.91	1.00
420	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	1700	0.91	1.00
430	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	1800	0.91	1.00
440	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	1900	0.90	0.99
450	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$	2000	0.90	0.99
460	$9 \cdot 10^{-5}$	$1 \cdot 10^{-4}$	2100	0.90	0.99
470	0.17	0.18	2200	0.89	0.98
480	0.66	0.73	2300	0.88	0.97
490	0.85	0.93	2400	0.87	0.96
500	0.89	0.98	2500	0.86	0.95
510	0.90	0.99	2600	0.83	0.91
520	0.90	0.99	2700	0.80	0.88
530	0.91	1.00	2800	0.25	0.27
540	0.91	1.00	2900	0.15	0.16
550	0.91	1.00	3000	0.11	0.12
560	0.91	1.00	3200	0.08	0.09
570	0.91	1.00	3400	0.07	0.08
580	0.91	1.00	3600	0.05	0.06
590	0.91	1.00	3800	0.05	0.06
600	0.91	1.00	4000	0.08	0.09
610	0.91	1.00	4200	0.06	0.07
620	0.91	1.00	4400	0.03	0.03
630	0.91	1.00	4600	$9 \cdot 10^{-4}$	0.001
640	0.91	1.00	4800	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$
650	0.91	1.00	5000	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$
660	0.91	1.00	5200	$<1 \cdot 10^{-5}$	$<1 \cdot 10^{-5}$
670	0.91	1.00			
680	0.91	1.00			
690	0.91	1.00			

n_d = 1.51680	ν_d = 64.17	$n_F - n_C$ = 0.008054	**N-BK7 517642.251**
n_e = 1.51872	ν_e = 63.96	$n_{F'} - n_{C'}$ = 0.008110	

Refractive Indices		
	λ [nm]	
$n_{2325.4}$	2325.4	1.48921
$n_{1970.1}$	1970.1	1.49495
$n_{1529.6}$	1529.6	1.50091
$n_{1060.0}$	1060.0	1.50669
n_t	1014.0	1.50731
n_s	852.1	1.50980
n_r	706.5	1.51289
n_C	656.3	1.51432
$n_{C'}$	643.8	1.51472
$n_{632.8}$	632.8	1.51509
n_D	589.3	1.51673
n_d	587.6	1.51680
n_e	546.1	1.51872
n_F	486.1	1.52238
$n_{F'}$	480.0	1.52283
n_g	435.8	1.52668
n_h	404.7	1.53024
n_i	365.0	1.53627
$n_{334.1}$	334.1	1.54272
$n_{312.6}$	312.6	1.54862
$n_{296.7}$	296.7	
$n_{280.4}$	280.4	
$n_{248.3}$	248.3	

Constants of Dispersion Formula	
B_1	$1.03961212 \cdot 10^{+00}$
B_2	$2.31792344 \cdot 10^{-01}$
B_3	$1.01046945 \cdot 10^{+00}$
C_1	$6.00069867 \cdot 10^{-03}$
C_2	$2.00179144 \cdot 10^{-02}$
C_3	$1.03560653 \cdot 10^{+02}$

Constants of Formula dn/dT	
D_0	$1.86 \cdot 10^{-06}$
D_1	$1.31 \cdot 10^{-08}$
D_2	$-1.37 \cdot 10^{-11}$
E_0	$4.34 \cdot 10^{-07}$
E_1	$6.27 \cdot 10^{-10}$
λ_{TK}[µm]	0.170

Internal Transmittance τ_i		
λ [nm]	τ_i [10 mm]	τ_i [25 mm]
2500	0.67	0.36
2325	0.79	0.56
1970	0.930	0.84
1530	0.992	0.980
1060	0.999	0.997
700	0.998	0.996
660	0.998	0.994
620	0.998	0.994
580	0.998	0.995
546	0.998	0.996
500	0.998	0.994
460	0.997	0.993
436	0.997	0.992
420	0.997	0.993
405	0.997	0.993
400	0.997	0.992
390	0.996	0.989
380	0.993	0.983
370	0.991	0.977
365	0.988	0.971
350	0.967	0.920
334	0.910	0.78
320	0.77	0.52
310	0.57	0.25
300	0.29	0.05
290	0.06	
280		
270		
260		
250		

Color Code	
λ_{80}/λ_5	33/29

Remarks	

Relative Partial Dispersion	
$P_{s,t}$	0.3098
$P_{C,s}$	0.5612
$P_{d,C}$	0.3076
$P_{e,d}$	0.2386
$P_{g,F}$	0.5349
$P_{i,h}$	0.7483
$P'_{s,t}$	0.3076
$P'_{C',s}$	0.6062
$P'_{d,C'}$	0.2566
$P'_{e,d}$	0.2370
$P'_{g,F'}$	0.4754
$P'_{i,h}$	0.7432

Deviation of Rel. Partial Dispersion ΔP from "Normal Line"	
$\Delta P_{C,t}$	0.0216
$\Delta P_{C,s}$	0.0087
$\Delta P_{F,e}$	-0.0009
$\Delta P_{g,F}$	-0.0009
$\Delta P_{i,g}$	0.0035

Other Properties	
$\alpha_{-30/+70°C}$[10^{-6}/K]	7.1
$\alpha_{+20/+300°C}$[10^{-6}/K]	8.3
Tg[°C]	557
$T_{10}^{13.0}$[°C]	557
$T_{10}^{7.6}$[°C]	719
c_p[J/(g·K)]	0.858
λ[W/(m·K)]	1.114
ρ[g/cm³]	2.51
E[10^3N/mm²]	82
µ	0.206
K[10^{-6}mm²/N]	2.77
$HK_{0.1/20}$	610
HG	3
B	0
CR	2
FR	0
SR	1
AR	2
PR	2.3

Temperature Coefficients of Refractive Index						
	$\Delta n_{rel}/\Delta T$[10^{-6}/K]			$\Delta n_{abs}/\Delta T$[10^{-6}/K]		
[°C]	1060.0	e	g	1060.0	e	g
-40/ -20	2.4	2.9	3.3	0.3	0.8	1.2
+20/+40	2.4	3.0	3.5	1.1	1.6	2.1
+60/+80	2.5	3.1	3.7	1.5	2.1	2.7

sinar

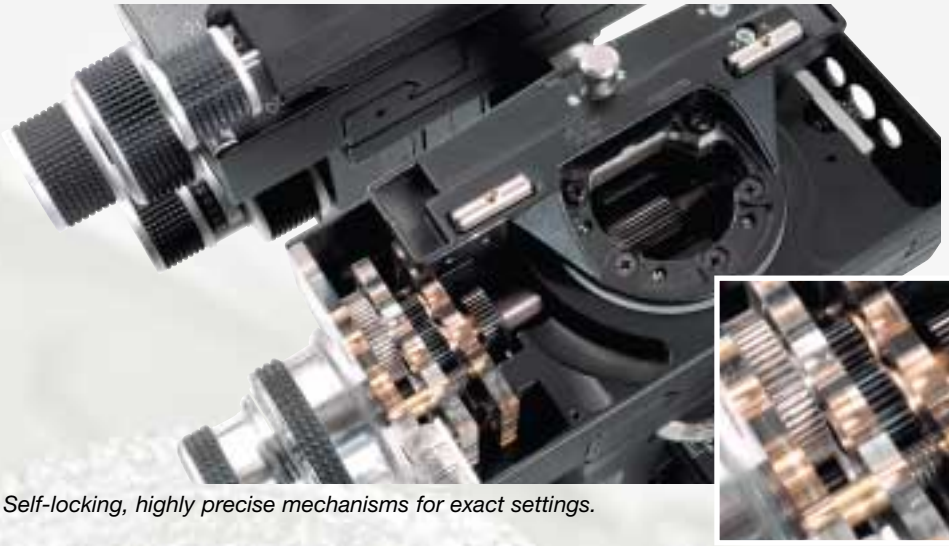
Sinar p3 View Camera

In the system with the Sinar m

The Legendary Precision of Sinar View Cameras...

Mechanical Precision

True to the tradition of the Sinar p line of view cameras, the Sinar p3 too, is equipped with highly precise mechanisms. In keeping with the requirements of digital photography, the dimensions of the new camera have been significantly reduced without sacrificing any of this traditional precision. The yaw-free camera with the proven segment swings and tilts and the asymmetrical swing and tilt axes permit an easy and exact positioning of the plane of sharpness. This ease of working is especially significant in digital object photography with high precision requirements. The self-locking fine drives keep the camera's standards exactly in the chosen position. The generous adjustment ranges, independent of one another, of the image standard and the lens standard (vertical and horizontal shifts as well as swings and tilts) provide the photographer with a maximum of creative freedom.



Self-locking, highly precise mechanisms for exact settings.

Ergonomic to the Last Detail

All the operating elements of the Sinar p3 camera are tailored to the size and the strength of the human hand. The ergonomic location of the operating elements makes precise and efficient work possible even in a darkened studio. In addition, snap locks on the elegant carrier frames permit quick and secure changes and adjustments of lenses, bellows and digital backs, thus enabling the photographer to concentrate entirely on the photograph itself.

Ergonomic design for convenient operation.

The Modular Design of the Sinar System

Of course the Sinar p3 camera too, is compatible with the Sinar System. Thanks to the extensive line of accessories, the modularly designed Sinar p3 can be tailored optimally to photographic tasks and to the needs of the photographer. An auxiliary standard designed specifically for the Sinar p3 serves for the use of long extensions. The optional sliding adapter permits the use of a focusing screen in addition to the live image on the monitor screen. Roll- or sheet films can also be exposed by means of the 4x5" metering back.

The Sinar p3 camera is compatible with several Sinar accessories.

...Combined with a State-of-the-Art Shutter...

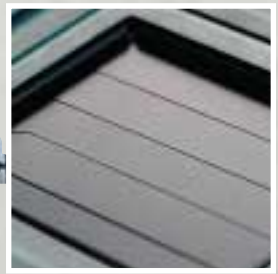
Sinar m **for Modern**

The Sinar m can be seen as a follow-up model in the successful Sinarcam series. It provides a modern behind-the-lens shutter system for the use with the Sinar p3. The camera functions can be controlled either via the display on the Sinar m or using the Sinar CaptureShop™ capturing software. Sinaron Digital Lenses built into the new, fully electronic Sinar auto aperture mounts (CAB) can also be operated using either the controls on the Sinar m or the capturing software. This is a considerable advantage for the user, particularly when the camera is in a raised position.

Sinar m: Professional camera shutter controlled either by software or by the integrated display.

Sinar m **for Mobile**

With shutter speeds of up to 1/2000th of a second, the Sinar m is the fastest view camera shutter system on the market. It is ideal, among other applications, for outdoor use in very bright light when fast shutter speeds are needed.
The Sinar m can be powered using either an external mains supply or by connecting it to an optional battery pack. In combination with the Sinar p3 and these accessories, the Sinar m constitutes the perfect system for even the most demanding jobs, in the studio or on location.



Sinar m: High-precision focal plain shutter with 1/2000th of a second shutter speed for the fastest professional view camera of all time – ideal for outdoor photography.

Sinar m **for Modular**

The Sinar m is more than just a shutter system for the Sinar p3 view camera. It is also exceptionally versatile, which will please those who are looking for flexibility and profitability for their money:
The Sinar m can be extended piece by piece to become a medium format or a 35 mm camera. Together with the Sinarback digital backs and a growing number of mirror modules for different makes of lenses it can be turned into either the perfect 35 mm camera, capable of taking extreme wide-angle shots; or, in combination with the Sinarback 54, into a medium format camera with the largest digital sensor on the market.
A selection of waist-level and prism viewfinders make the Sinar m the first camera for universal usage.
Microprocessors in all modules ensure that the components interact perfectly, guaranteeing the highest precision and reliability.

Sinar m: Extendable to become a medium format or 35 mm camera. With electronically controlled mirror modules – ideal for digital photography.

...Optimized for the Digital Era.

Intelligently Digital

The Sinar p3 has been tailored uncompromisingly to function with Sinarback high-end digital backs. For this reason, electrical contacts have mostly been integrated into the camera, and the number of cables required reduced to a minimum. Depending on the type of Sinarback used, data transfer is carried out either via a modern firewire connection, or via a well-proven fiberoptic connection. This way the Sinar p3 is well-equipped for use both in the studio and also, in combination with a Notebook, on location.
Combined with the optional Liquid Crystal Shutter, the live image allows perfect focusing with maximum ease.

Integrated cabling and gold-plated contacts for dependable, computer-controlled operation.

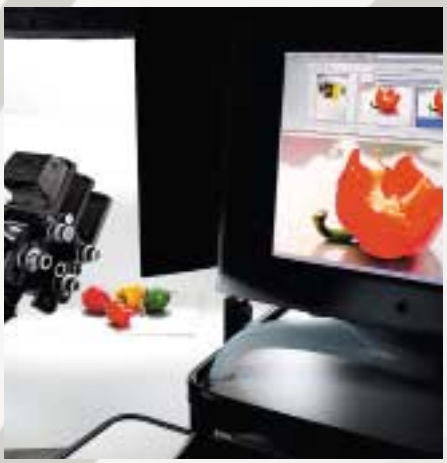
Sinaron Digital Lenses

With the Sinaron Digital series, Sinar offers a comprehensive range of lenses that are optimally tailored to the resolution of the high-end CCD sensors. These lenses provide the photographer maximum sharpness of focus, high contrast, and outstanding color fidelity.
There are two different lens mounts available. For use with the Sinar m, the lenses can be built in the auto aperture mount (CAB). This allows for comfortable operation either through the camera or the capturing software, and shutter speeds of up to 1/2000th of a second can be achieved. These lenses are available with focal lengths between 28 and 210 mm.
Used in combination with the Sinar p3, with or without the Sinar m, the lenses can be built into compact, electronic between-the-lens shutters with shutter speeds of up to 1/60th of a second and manual aperture control (CMV). Lenses in this mount are available from 28 to 150 mm.

High-resolution Sinaron Digital lenses perfectly matching the requirements of digital photography in a compact design.

For Every Photographic Task

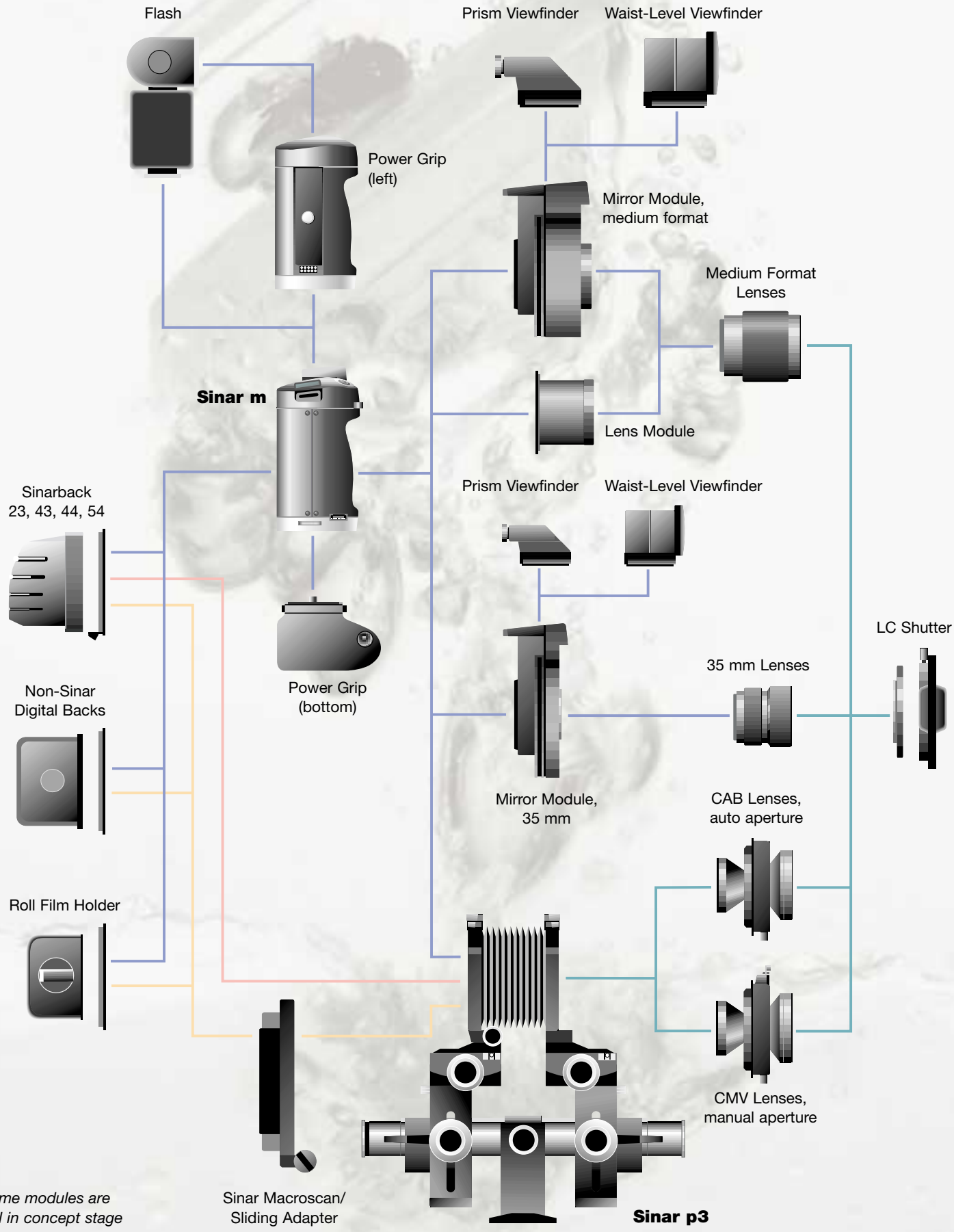
With Sinar you have a system that guarantees you extendibility, investment security and compatibility well into the future.
The centerpiece is the new Sinar m, which can be used either as a shutter system for the professional view camera, or as a medium format or 35 mm camera.
The Sinar system is completed by a vast choice of components and accessories, which ensure that, even in years to come, your camera will still be the newest and best available.



A tidy working area in the studio, optimized for digital photography.

Thanks to its compatibility with Sinar System components, the Sinar p3 can also be used with conventional film.

...Integrated in a System Geared to the Future.



Some modules are still in concept stage

Sinar – Better Images Thanks to Modularity and Innovation

Perspective Correction and Sharpness Compensation

Make life easy for yourself – with the adjustment capabilities of the Sinar p3 view camera. The generous adjustment range permits precise focusing, even with difficult subjects, thus preventing lengthy subsequent manipulation. Two-point focusing and sharpness compensation, made particularly easy thanks to the asymmetrical swing- and tilt axes, produces brilliant photographs – for digital applications as well as on film.

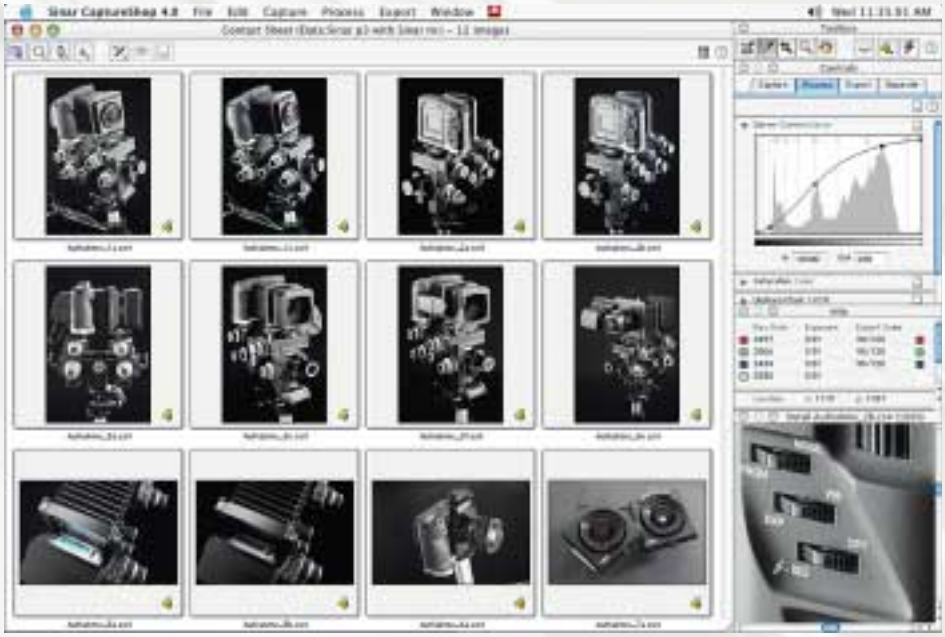
Difficult subjects, photographed in sharp focus and with perspective correction, prevent complex and costly subsequent manipulation.

Full Integration into the Sinar CaptureShop™

The Sinar p3 camera is the ideal platform for digital photography, because its technical capabilities are completely integrated into the Sinar CaptureShop™ capturing software. The swing- and tilt axes of the Sinar p3 camera are displayed directly on the live image on the computer screen. That makes it possible to position the plane of sharpness quickly and with pixel accuracy, even with very complex subjects. An electronic grid overlay on the monitor screen makes it easy to align the subject. In addition, layouts can be placed directly over the live monitor image electronically, which further facilitates the composition of the photograph.

The Free Choice of Resolution

The Sinar p3 camera is compatible with current and future Sinarback digital backs. In order to satisfy diverse requirements, Sinarback models are available with different sensor sizes and resolutions. The addition of a Sinar Macroscan provides a major increase in resolution and, thanks to the greater imaging surface, an optimal benefit from the adjustment capabilities of the camera.



Computer-aided operation for perfect multi-shot exposures with the greatest color fidelity and resolution.

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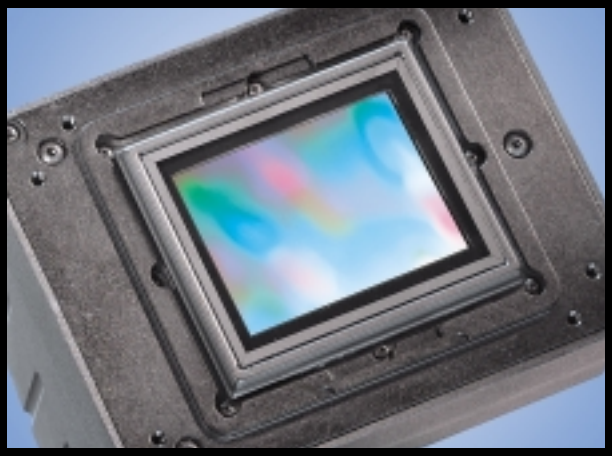
Sinarback 54

High Resolution Digital Large Format

The most modern technology for better photographs

Sensor

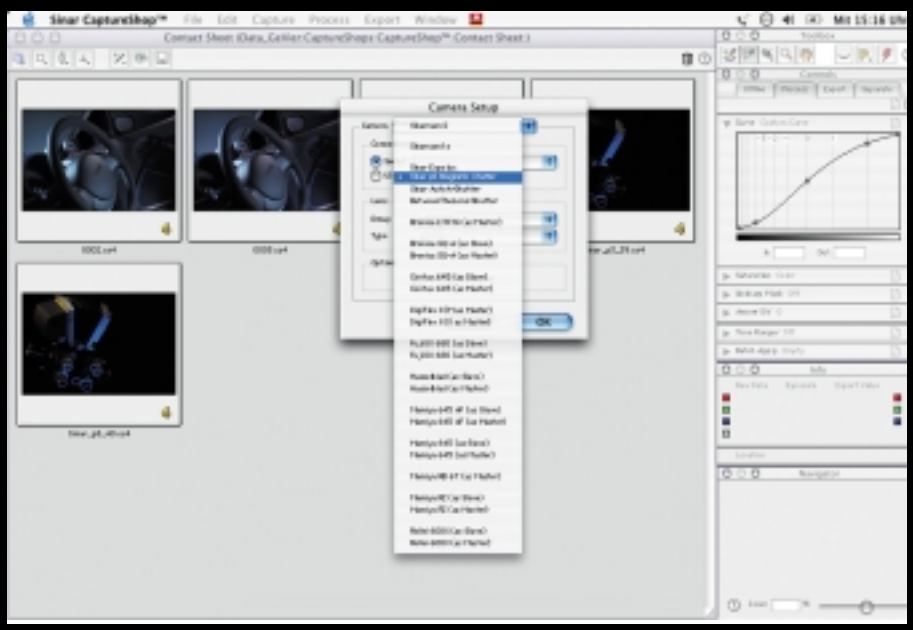


Developed by Kodak in cooperation with Sinar, the KAF-22000CE sensor features a new color pigmentation for the best possible color stability and for a greater dynamic range. The combination of the large 38.8 mm x 50.0 mm optical format (a ratio of 4:3) of the sensor with 4080 x 5440 pixels with an edge length of 9/1000 mm leads to a truly sensational image quality.

1-/4- and 16-Shot

For fashion, people, nature and architectural photography and for all other moving subjects, the Sinarback 54 is the ultimate solution. For specialized photographers, Sinar offers the Sinarback 54 S as purely 1-shot digital back. In addition, for perfect still-life photographs there is also the Sinarback 54 H with 4-shot capability for perfect colors and also 16-shot capability for the finest detail rendition.

Active sensor cooling, anti-moiré and all the advantages of Sinar CaptureShop™ exposure software.



It is a matter of course that the new Sinarback 54 incorporates all the advantages of the Sinarback line, such as: active direct thermoelectric cooling of the sensor for the suppression of noise, hardware anti-moiré for the reduction of the moiré effect, for instance in very delicate detail structures of textile fabrics. And the comprehensive advantages of Sinar CaptureShop™ exposure software with free-of-charge upgrades.

Nothing | can | replace | resolution...

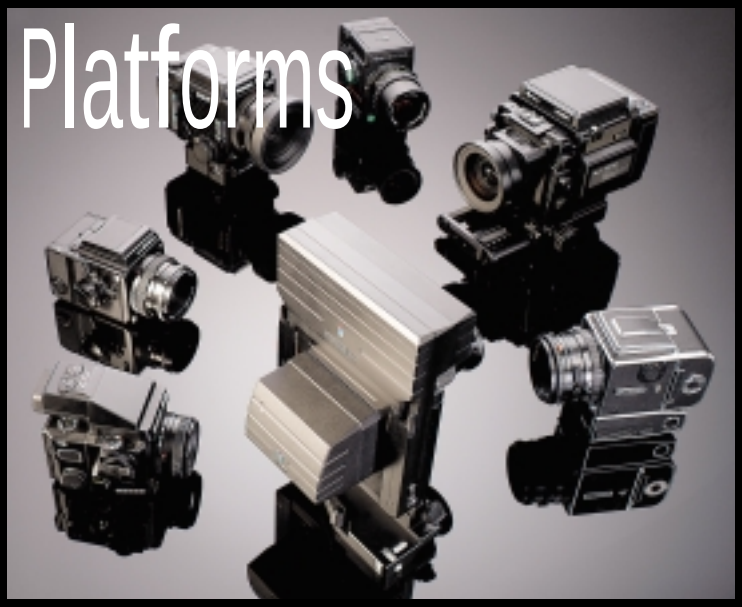
Difficult subjects in the 1-shot mode are captured with perfection by the Sinarback 54, thanks to its outstanding resolution, award-winning color fidelity and active cooling of the sensor for the highest possible dynamic range.

...except | more | resolution

Resolution with a sharp bite: The new Sinarback 54 makes photographs possible with unique sharpness, brilliance, in the rectangular format and with the detail fidelity of large format camera.

Camera Platforms

Sinarback 54



Technical Data

Sinarback Digital Backs

- Digital camera back for exposures made with any kind of light:
  Sinarback 54 H: 1-, 4- and 16-shot
  Sinarback 54 S: 1-shot
- Sensor dimensions:
  Sinarback 54: 49,0 mm x 36,7 mm
- Sensor resolution:
  Sinarback 54: 5440 x 4080 pixels
- Data sizes (at 16 bit TIFF):
  Sinarback 54:
  1-shot 130 MB; 4-shot 130 MB;
  16-shot 510 MB
- Full color information without color interpolation in the 4- and 16-shot modes

The new Sinarback 54 can be adapted to practically all medium format cameras. This eliminates the limitation to a specific camera system. To change the camera, all the photographer needs to do is to change adapter boards. That makes it possible to achieve the maximum resolution of more than 22 million pixels with most modern medium format cameras practically without the need for increased focal lengths. The Sinarback 54 can be used universally with most computers without modifications.

Sinar System for every application

Size counts!

For more than 50 years the name Sinar has been standing for a comprehensive modular camera system in the field of high-end studio photography – always based on the principle of "better photographs".

With the new Sinarback 54, digital technology is also entering the realm of 1-shot large format photography – ideal for all applications in studios, for architecture, landscapes, using the very same digital back on almost every medium format camera without a significant need for an increased focal lengths.

With the new Sinar m camera, Sinar is the very first manufacturer to offer a fully modular high-end camera for use with 35 mm camera lenses, medium format lenses and Sinaron digital lenses.

The Sinar p3 is a view camera optimized for digital photography - ideal for mobile applications and, of course, for studio applications as well. With integrated cabling, a shutter with very low vibration and asymmetrical swing- and tilt axes in a live image, it represents the optimal digital studio solution.

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The first sensibly modular camera system in the world!

Sinar m

The digital camera for every professional application

A truly modular camera system

Fully automatic shutter system for the Sinar p3 view camera

Regardless of whether it is used with Sinaron digital lenses, 35 mm camera lenses or medium format camera lenses, the Sinar m fits perfectly in the hand – and with only a twist of the wrist it also serves perfectly as a shutter on the Sinar p3 view camera.

A digital camera for 35 mm, medium format, and Sinaron digital lenses

Mobile System

The Sinar m has been optimally tailored for use with Sinarback digital backs. For example, it is also ideally suited for mobile use on location, in combination with the Sinar Cyber Kit or with a notebook – and roll film capability is also planned for the near future!

A choice of formats and media

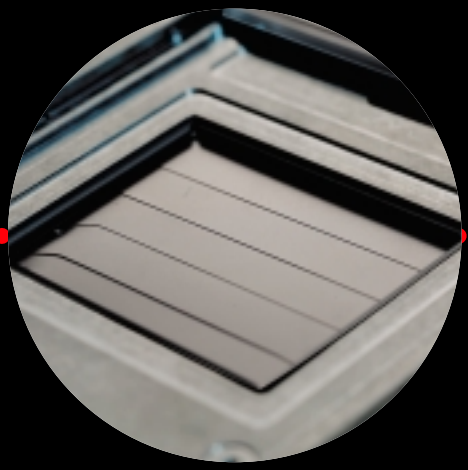
Powerteam: Sinarback and Sinar m

Sensible modularity ranging from a 35 mm camera all the way to a view camera

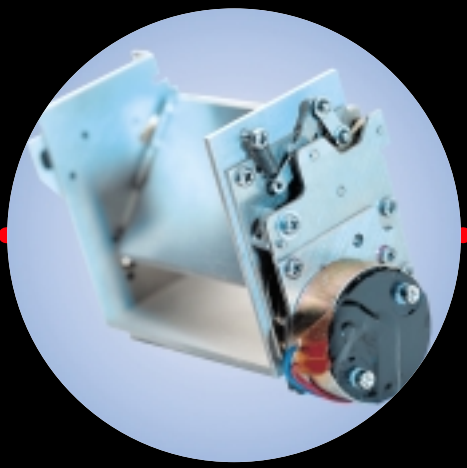
A comprehensive, highly versatile system: The Sinar m offers an enormous spectrum of application possibilities and it is optimally integrated into the Sinar system.
It is in combination with Sinarback digital backs that the new Sinar m shows its true greatness. Digital Sinaron lenses render the very best image quality, and the Sinarback 54 with its more than 22 million pixels produces photographs with never before seen brilliance, sharpness and color fidelity.

The technology of the Sinar m

Straight-, prism- as well as zoom sports viewfinders can be used – exactly the right module for every task!



Sinar m: Shutter speeds from 32 sec. to 1/4000 sec. – Size: 4.5 cm x 6.0 cm! Now there are no more limitations to outdoor photography with the Sinar m camera.



A Sinar exclusive: Very low vibration, exchangeable mirror reflex modules with electronically controlled action – optimized for digital photography!

The display conveniently shows the settings and most important camera functions – so you can keep control.

A truly revolutionary system

For more than 50 years the name Sinar has been standing for a comprehensive modular system in the field of high-end studio photography – always with the objective of “better photographs”.

Now, with the new Sinar m, Sinar opens a new chapter in the history of the design of cameras. A system so versatile that it is a 35 mm camera, a medium format camera and a view camera – all at the same time – for use with traditional film or for digital imaging.

It is modular, so that it can be tailored to be exactly the perfect professional system for every application.

Optimized for use in conjunction with Sinarback digital backs, the Sinar m is the very first professional camera that was designed from the ground up specifically for digital photography.

Ergonomically positioned switches and innovative operating concepts – for professional use!

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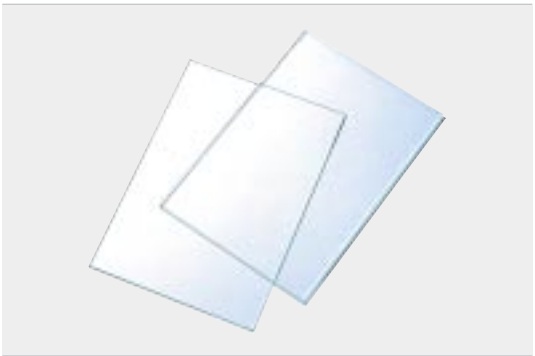
unaxis
OPTICS

Calflex X™

Broadband Near-Infrared (NIR) Blocking Filter

Unaxis Optics NIR-blocking filter Calflex X™ is commonly used to shield sensitive equipment such as silicon cells from harmful NIR-radiation. It combines extremely high NIR-suppression and sharp transition slope.
Dielectric oxide coating design provides excellent transmission over the entire visible spectrum and sharp transition to reflection in the infrared.



Benefits

- Extremely high NIR-reflection
- High visible transmission
- Sharp transition from transmission to reflection
- No color degradation
- May be used as heat protection filter
- Heat rejection independent of glass thickness
- Mechanically and chemically durable dielectric coating

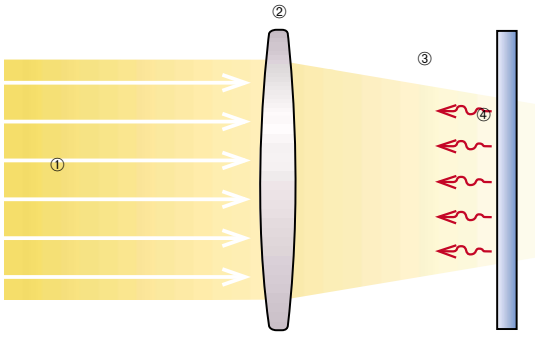
Technical Data

Temperature resistance	up to 250 °C
Spectral characteristics, AOI = 0°	
T abs.	1% for λ = 780–1100 nm
T =	50% for λ = 730± 20 nm
T abs.	80% for λ = 425– 680 nm
Standard size	160 x 110 x 1.1 mm

Applications

- Improving signal to noise ratio of silicon detectors
- Protection of silicon photodiodes
- Improved sensitivity of light barriers
- Trimming of photodiodes
- Signal/noise ratio improvements for digital image sensors
- Heat/light separation

Schematic of filter integration to sensor package

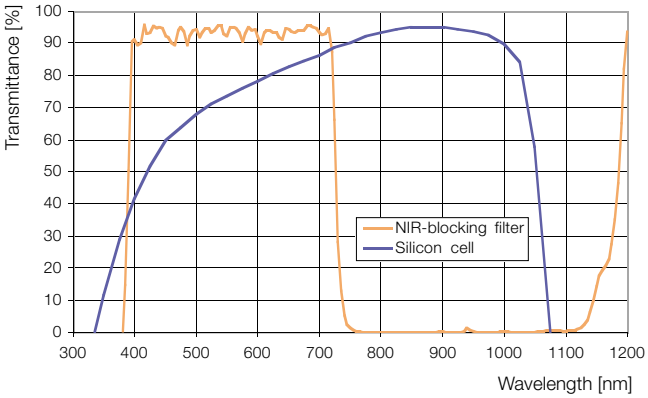


① Visible + IR-radiation
② Lens
③ NIR-blocking filter
④ Sensor

colored by unaxis

Unaxis Optics
the future of
Balzers Thin Films

NIR-blocking filter
and sensitivity of silicon cell



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